THE MECHANICAL APPLIANCES

OF THE

CHEMICAL AND METALLURGICAL INDUSTRIES

A COMPLETE DESCRIPTION OF THE MACHINES AND APPARATUS USED IN CHEMICAL AND METALLURGICAL PROCESSES FOR CHEMISTS, METALLURGISTS, ENGINEERS, MANUFACTURERS, SUPERINTENDENTS AND STUDENTS.

BY

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With 292 Illustrations

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PREFACE.

The aim of this book is to clear up ideas regarding the mechanical appliances used in the chemical and metallurgical industries, to expose the real importance of the machines used in the various processes and to get rid of the obscurities prevailing at present in these matters. I hope that this treatise will fill a deeply felt want, as there is only one book on the market, along similar lines, viz., Parnicke's well-known German work.

I have treated with great detail all the prominent types of machines, which are of interest to the industrial chemist and metallurgist. The subject, however, being so wide, proper selections had to be made—as always in such cases—according to my judgment and experience.

Holding the view that that man will be the best judge of a group or class of things who is familiar with the highest standard and best type of same, I have described in every chapter the best respective machines on the American market. I hope that in this respect the chapters on transportation of gases, liquids and solids, on grinding, mixing, filtering, concentrating, drying, firing, etc., will give considerable enlightenment to readers interested in these subjects.

The chapters on power have been treated from a more general point of view. As to steam power, I have not gone into detailed description of steam boilers and steam engines, but have mainly dwelt upon the requirements of a perfect steam boiler and the care of boilers. However, regarding superheated steam, turbines, and especially gas power, I have said everything that is of interest to the chemical and metallurgical engineer.

Another object of this book is to impart such information as to make buyers of machinery independent of the "talking points" of the salesman. The buyer, being familiar with the best types of machines, will easily see if any essential details are lacking in a machine offered to him.

I also hope that this book will prove highly useful to the student, analytical chemist and to the mechanical engineer connected with the chemical industries, as also to manufacturers, superintendents and purchasing agents in general.

OSKAR NAGEL, PH.D.

NEW YORK,
November, 1908.

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CHAPTER I.

GENERAL.

Covering and Packing. The loss by radiation from unclothed pipes and vessels containing steam is considerable, and, in the case of pipes leading to steam engines, is magnified by the action of the condensed water in the cylinder. It therefore is important that such pipes should be well protected.

There is a wide difference in the value of different substances for protection from radiation, their value varying nearly in the inverse ratio of their conducting power for heat, up to their ability to transmit as much heat as the surface of the pipe will radiate, after which they become detrimental, rather than useful, as covering. This point is reached nearly at baked clay or brick.

A smooth or polished surface is of itself a good protection, polished tin or Russia iron having a ratio, for radiation, of 53 to 100 for cast iron. Mere color makes but little difference.

Hair or wool felt, and most of the better non-conductors, have the disadvantage of becoming soon charred from the heat of steam at high pressure, and sometimes from taking fire therefrom.

Mineral wool, a fibrous material made from blast furnace slag,

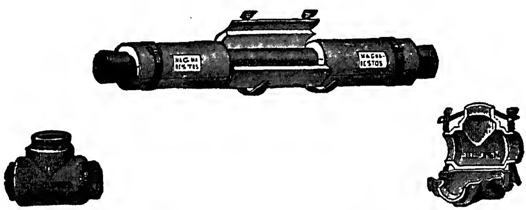


FIG. 1. MAGNESIA COVERING.

is the best non-combustible covering, but is quite brittle and liable to fall to powder where much jarring exists.

Air space alone is one of the poorest of non-conductors, though the best owe their efficiency to the numerous minute air cells in their structure. This is best seen in the value of different forms of carbon, from cork charcoal to anthracite dust, the former being three times as valuable for this purpose, though in chemical constitution they are practically identical.

Any suitable substance used to prevent the escape of steam heat should not be less than one inch thick.

Fig. 1 shows a sectional magnesia covering made by the Crane Co., Chicago, Ill. These coverings come in regular lengths of three feet; they are canvas covered and have two sheet-iron bands to each length.

For covering steam pipes, boilers, heaters, etc., asbestos cement felting is frequently used. This covering is composed of asbestos fiber combined with other non-conducting materials and makes a light, non-combustible and durable covering. It is put up in barrels dry to be mixed with water to the consistency of mortar and is applied with a trowel.

An everyday operation is the packing of stuffing boxes, a great

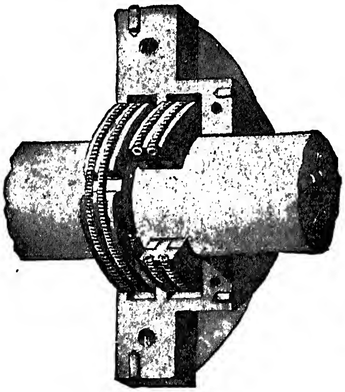


Fig. 2. Morris Metallic Packing.

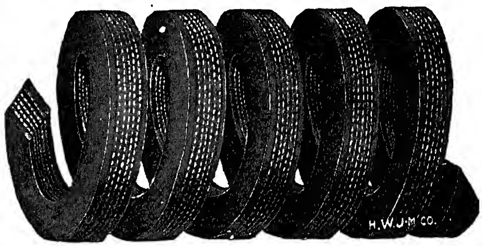


Fig. 3. Spiral Packing.

variety of suitable products being on the market for this purpose.

Fig. 2 shows the Morris metallic packing for reciprocating piston rods and stems which is so constructed that while it holds both vacuum and steam pressure, it insures a minimum of friction, from the fact that the wedge principle is entirely eliminated. This packing is automatically lubricated by the cylinder oil carried over by the steam through the sectional rings to the bearing surface.

Fig. 3 shows a spiral packing which is made to meet a demand for a cloth and rubber packing for medium and low pressure steam and is especially adapted for use in connection with metallic rings where the service is against saturated steam.

A satisfactory packing for engines using superheated or satu-

rated steam is the Duval metallic packing shown in Fig. 4, which consists of a mass of fine composition wire plaited into square form. Each individual wire is coated with anti-friction metal. No special form of stuffing box is required for this packing, which is flexible and readily bent around a rod or plunger.

For packing pipes, gaskets made of rubber, asbestos, copper, etc., are used. Fig. 5 shows a metallic gasket consisting of thin sheet copper stamped with concentric corrugations. Three to six corrugations are all that are necessary, so that the space within the bolt holes determines the width of the gasket. In cases where the flanges are thin and for this reason liable to bend when the bolts

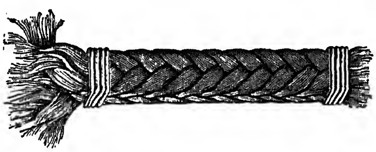


FIG. 4. DUVAL PACKING.

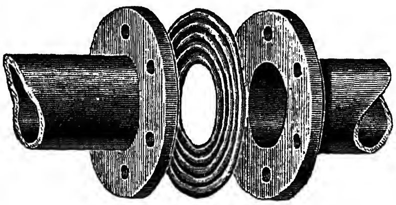


FIG. 5. METALLIC GASKET.

are tightened, it is advisable to extend the copper gasket to the full width of flange. This width of course requires the cutting of bolt holes in the gasket. Connections made with these gaskets will not blow out in continued use, for each corrugation makes the entire circle of the flange, and so long as the contact is kept complete by compression, the joint cannot leak.

In long pipe lines through which hot liquids or gases are conveyed expansion joints have to be inserted at certain distances, about every three hundred feet, for equalizing the expension caused by the heat.

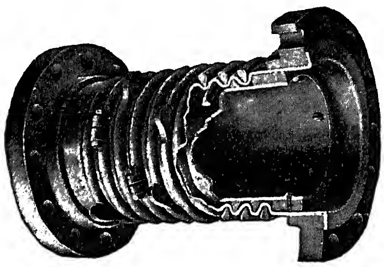


FIG. 6. EXPANSION JOINT.

Fig. 6 shows a Wainwright expansion joint which is largely used for superheated steam. These expansion joints which are manufactured by the Alberger Condenser Co., of New York, are very compact, being no larger than the diameter of the flanges of the pipe in which they are inserted; they are entirely free from leakage and so made that they can be readily covered with a non-conducting material to prevent radiation of heat.

This expansion joint consists of a main corrugated tube of soft copper, an inner cylindrical slip tube of hard copper or composition, external and internal equalizing rings of cast iron, and connecting flanges of cast iron or steel. The function of the corrugated tube is obvious. It withstands the internal pressure and makes an absolutely steam-tight connection from one end to the other. The equalizing rings are used to limit the movement of the corrugated tube in any one convolution and to cause all of the latter to assume their part of the travel. In this manner not only is a very effective result obtained, but the durability of the device is also assured.

Pipe lines for hot or cold pressure water, acids and lyes are preferably made with flanged joints. With lead pipes great lengths are soldered together and the flanges reduced to the smallest possible number.

Suction lines for cold water are made with screwed joints and packed with rubber and asbestos. The packing of distillation and extraction apparatus depends upon the material to be treated.

Cocks and Valves. For interrupting the flow of liquids and gases cocks and valves are inserted in the pipe lines. Fig. 7 shows

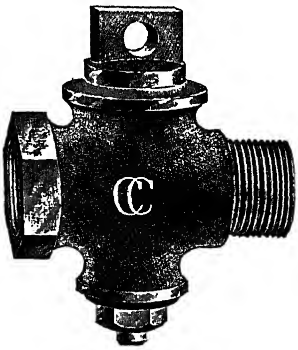


Fig. 7. Standard Steam Cock.

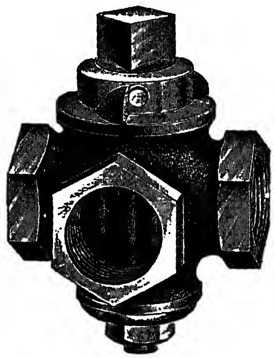


Fig. 8. Three Way Cock.

a standard steam cock, Fig. 8 a three-way cock. For strongly acid liquids and gases stoneware cocks are used.

Valves are used to a much larger extent than cocks, as they allow a better regulation and a gradual interruption of the flow of liquids and gases.

The sectional view of the well-known Jenkins brass globe valve is illustrated in Fig. 9. *1* is the wheel, *2* the lock nut, *3* the spindle, *4* the bonnet, *5* the disc holder, *6* the disc, *7* the waste nut, *8* the wheel nut, *9* the disc nut and *10* the body.

A complete line of the most excellent valves of all kinds and sizes is made by the Schutte and Koerting Co., Philadelphia.

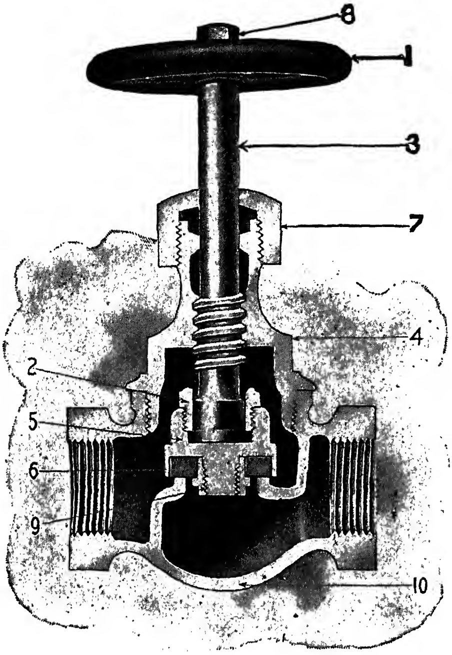


FIG. 9. BRASS GLOBE VALVE.

Fig. 10 shows the Schutte stop valve made of new metal (copper and tin). For superheated steam this valve is made of nickel bronze. A stop check valve made by the same concern built for

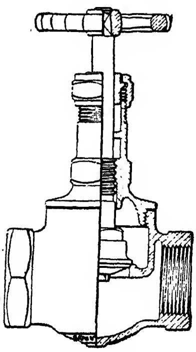


FIG. 10. STOP VALVE.

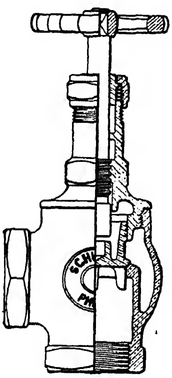


FIG. 11. STOP CHECK VALVE.

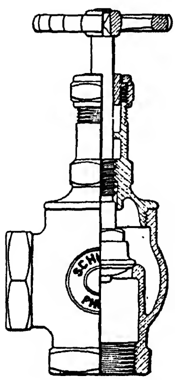


FIG. 12. WATER VALVE.

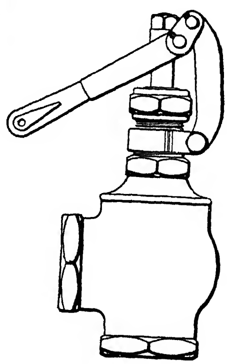


FIG. 13. LEVER VALVE.

use on cylinder drains and boiler feed lines is illustrated in Fig. 1
These valves do the combined services of stop and check valve
thereby saving the cost of one valve.

A valve which is extensively used as water valve, especially
mines, is shown in Fig. 12. This valve is provided with leather
hard rubber renewable discs, that are easily put in.

For conditions where stopping or starting is required by o
quick movement the lever valve shown in Fig. 13 is to be use
These valves are also applied for operating steam jet exhauste
and are very convenient in connection with automatic floats.

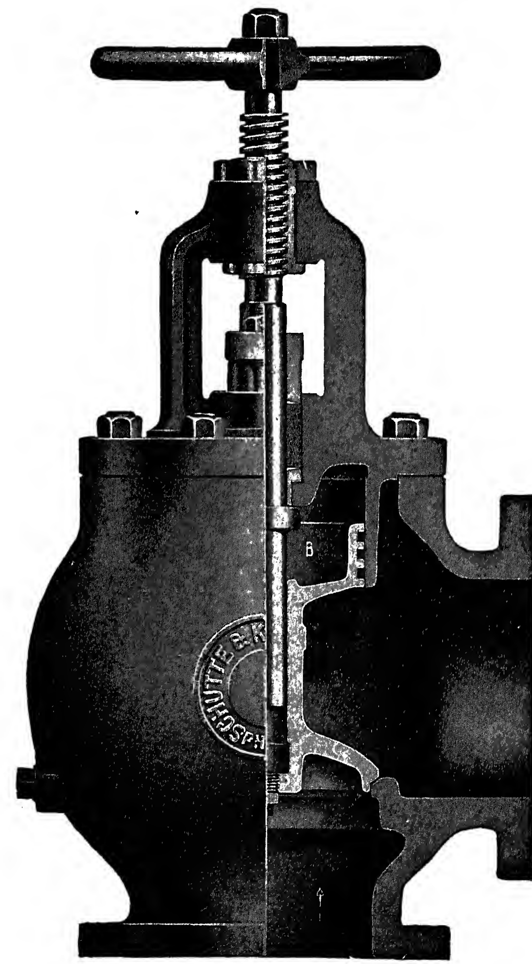


FIG. 14. AUTOMATIC STOP CHECK VALVE.

Fig. 14 shows the Schutte automatic noiseless stop check valve which is inserted in the connection from each boiler to the main steam pipe to prevent the back flow from the main steam pipe when

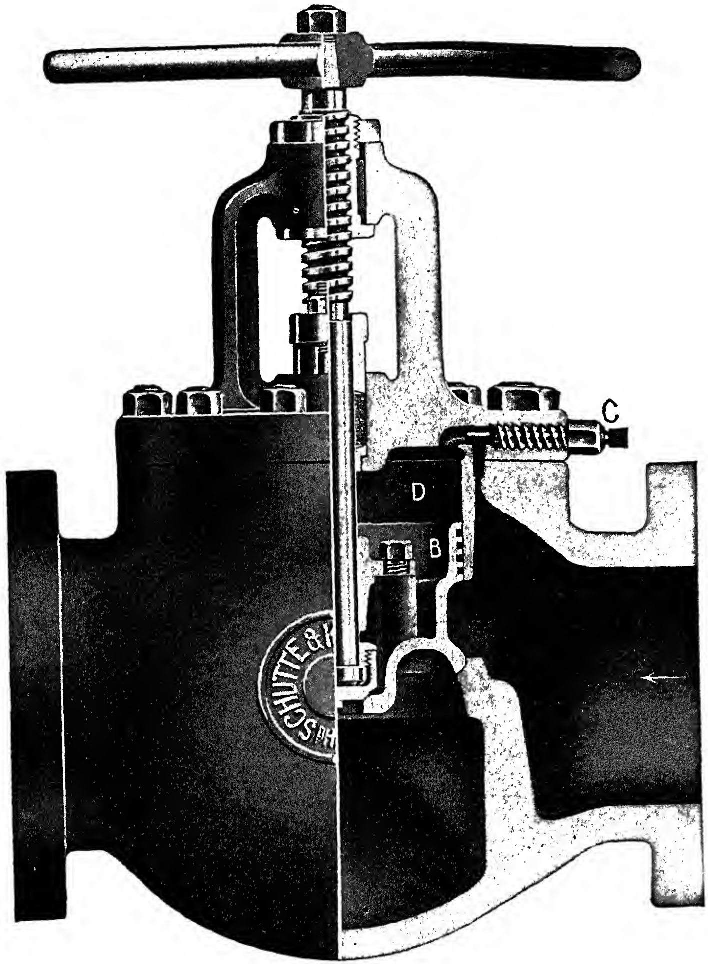


FIG. 15. BALANCED VALVE.

the pressure in one boiler is lower. Such conditions always occur when starting a fire or when a joint or tube breaks in a boiler.

When the fire under the boiler is deficient or not properly attended to the check will indicate that its fire needs attention by a slight rattling sound at intervals, caused by the intermittent discharge from the boiler to the main steam pipe. By making this

check valve a stop check valve it answers at the same time as a stop valve, which every boiler must have.

The fluctuation of pressure in the main steam pipe, caused by the automatic cut off of engines, causes a back-lash against the disc of the valve, tending to drive it down to the seat. This back-lash is absorbed in an upward direction by piston *B* which is approximately the same diameter as the disc, hence the blow is equalized in both directions irrespective of positions of the disc. The chamber above

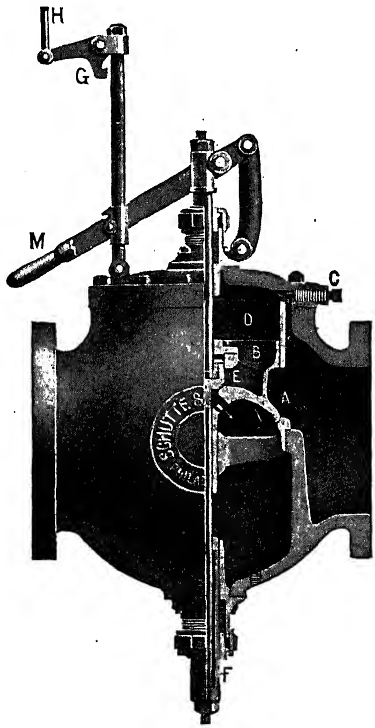


FIG. 16. BALANCED TRIP VALVE.

piston *B* is not a dash pot but simply a cylinder, whereby a constant pressure is maintained above, as well as below, the seat.

Balanced Valves. The object of balancing the valve is to remove the strain from the spindle so that its operation can be effected quickly and with least effort.

The construction of the Schutte valve (balanced) shown in Fig. 15 is based upon the principle of a loose fitting piston, connected directly with the valve disc, whereby the valve is balanced.

The operation is as follows: The first movement of the hand wheel opens the by-pass and relieves the pressure in cylinder *D*, thus balancing the valve. The piston *B* is not tight fitting, but permits steam to leak past, as also a portion controlled by plug *C*. The flow then passes through the by-pass and warms up the connections. The steam must enter above the seat.

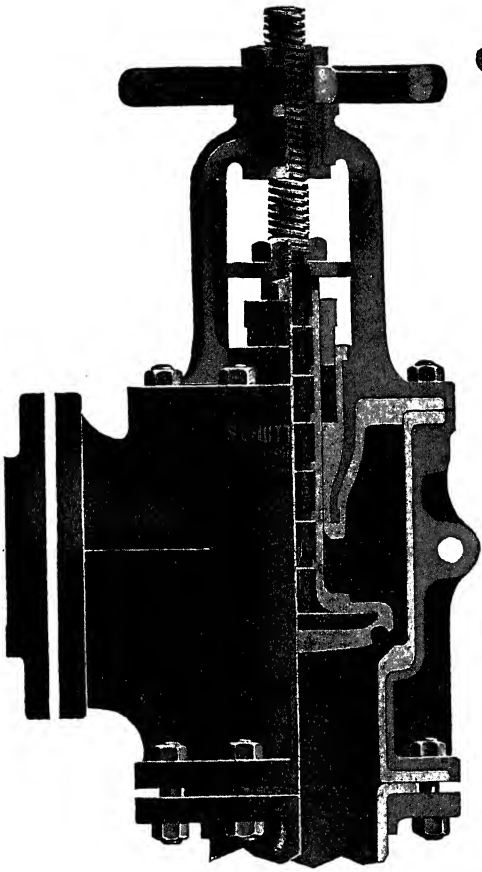


FIG. 17. LEAD LINED VALVE.

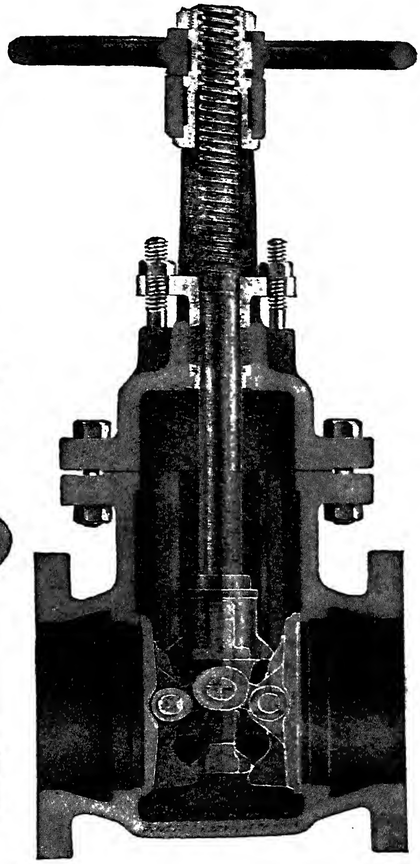


FIG. 18. PRECISION GATE VALVE.

Balanced Trip Valves and Trip Throttle Valves. These valves are intended as emergency shut-off or engine stop valves and may be operated either by hand, or with electric solenoid and push button, or automatically by governor attached direct to engine.

The trip valves are used in steam pipe connection to engine and are operated independent of the throttle valve. The trip throttle

valves combine the features of a trip and throttle, thereby avoiding the necessity of two valves. They also have the advantage of being handled daily whereby they are kept in perfect condition; while a separate trip valve may, through lack of attention or use from time to time, fail to work when required.

Fig. 16 shows a Schutte balanced trip valve provided at the bottom with a small sleeve *F*. The valve is locked open by moving the hand lever up till the catch on same engages with the lever *G* supported on the upright bar. After the valve is open, steam pressure acts on the area of the piston *F* with continuous downward force, which causes the valve to close as soon as the catch is released. A hand lever attached to rod *H*, the rod being extended to any desired point, will permit the operation promptly and without effort. For automatic operation of the valve, the rod *H* may be connected to any suitable mechanism as to the engine governor, to direct-connected cylinder operated by air, steam or hydraulic pressure or to electrically actuated devices.

Fig. 17 shows the Schutte lead-lined valve. Every part of this valve coming in contact with the liquid is lined with lead. This valve, which is widely used in chemical factories, is made in the angle form only. When used in a straight pipe line, connection has to be made accordingly. A lead-lined check valve having for a check a solid ball made either of earthenware or hard rubber is manufactured by the same firm.

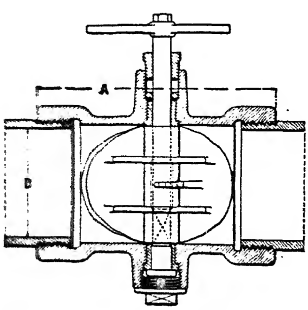


FIG. 19. BUTTERFLY VALVE.

Gate Valves. With these valves the direction of the flow is not changed and the cross-sectional area not decreased. The Schutte precision gate valve shown in Fig. 18 is a good illustration for this type.

A valve which is not perfectly tight but is frequently used where absolute tightness is not required, is the butterfly valve shown in Fig. 19.

When it is desired to operate valves from a floor above, the extension rod and stand, as shown in Fig. 20, may be used. The lever or wheel is removed from the valve spindle and attached to the top of the extension rod, while the rod is connected to the valve by a yoke or nut.

Gas Reversing Valves. In the industries in which producer gas is used as fuel in connection with regenerators, valves are used for reversing the current of gas. The old Siemens butterfly valve which is widely used, though considerable losses are occurring in same on account of leaks, is now being superseded by more modern constructions.

Figs. 21, 22 show a gas reversing valve of modern construction which is successfully used in a large number of European iron

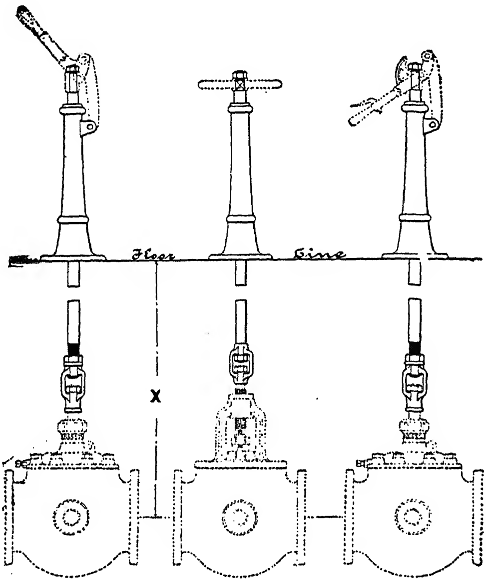


FIG. 20. EXTENSION ROD AND STAND.

works. It has the advantage that it keeps tight for many years, does not warp and effects a saving in fuel which in many cases is very considerable.

This valve which is called the Fischer valve consists of three main parts, namely, an inner cylinder with a wall across; an outer cylinder which is made in four compartments with four ribs, and the base-plate.

The inner cylinder *a* presses by the weight *b* to the lower face *c* of the upper ring, whereby the upper joint is kept tight. The space of play between the inner cylinder and outer cylinder can be made as desired and the connection between the two cylinders is made by four ribs *d*, which effect a tight joint on the sides. The four

ribs are pressed by the weights *e* against the inner cylinder. The ribs *d* can be lifted by loosening the bolts *i*, whereby a connection is made from producer to stack for burning out the pipes, etc. The lower joint is made tight by having the inner cylinder resting in

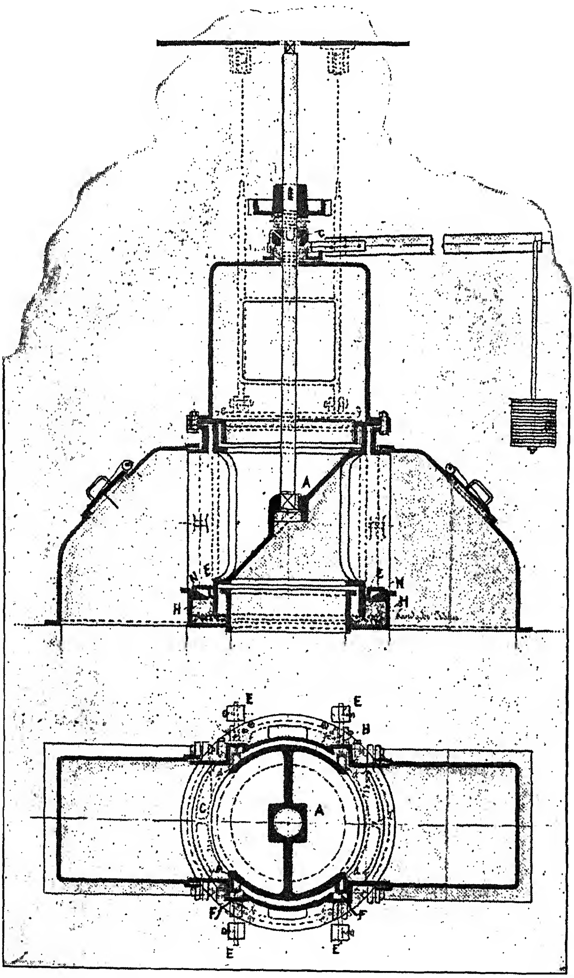


FIG. 21. GAS REVERSING VALVE.

sand *h* on the base-plates. The pieces *l* prevent a throwing out of the center. The inner cylinder rests in ball-bearing *o* which allows easy handling and rests on the button *p* whereby an absolutely horizontal position of the inner cylinder is effected.

The gas current is reversed by turning the valve 180 degrees.

Steam Traps. For removing condensed water from steam pipe lines steam traps are used, their construction being based upon one of the following principles: (1) Expansion of metals by heat and contraction of same by cooling; (2) the buoyancy of the liquid col-

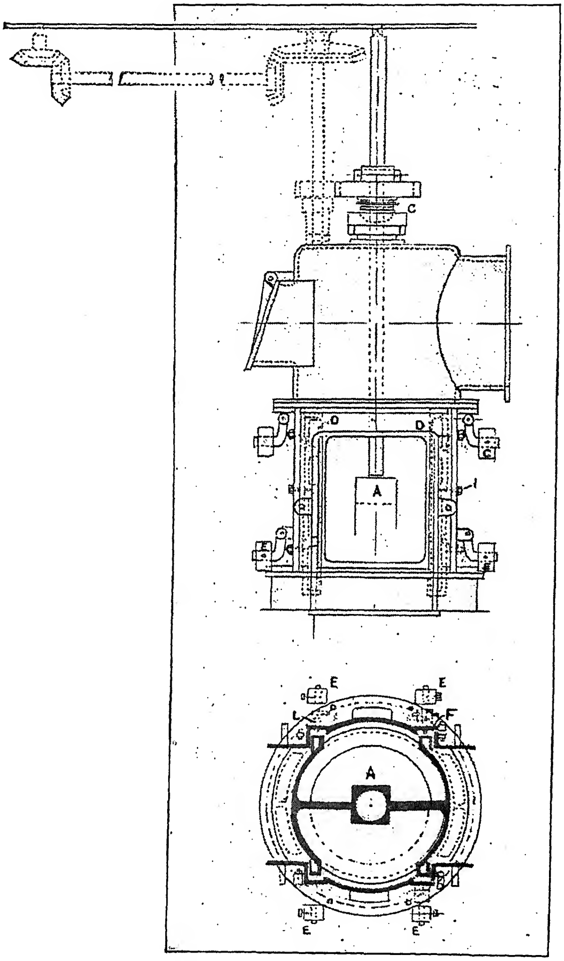


FIG. 22. GAS REVERSING VALVE.

lecting in a vessel; (3) the use of the weight of the liquid for opening cocks or valves of suitable construction, whereby the water is allowed to run off while the steam following is retained.

The expansion steam trap shown in Fig. 23 and Howland's im-

proved steam trap shown in Fig. 24 are readily understood from the illustration; Fig. 25 shows a sectional view of the Jenkins

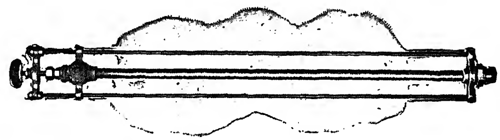


FIG. 23. EXPANSION STEAM TRAP.

Diamond trap which is well adapted for places where there is a moderate amount of condensation which it is desired to remove without waste of steam. It is perfectly automatic and when properly adjusted will remain open as long as water escapes, closing instantly when steam strikes the plug.

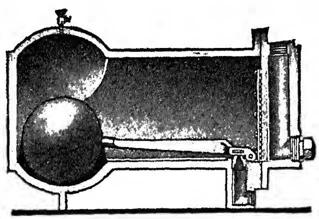


FIG. 24. HOWLAND'S STEAM TRAP.

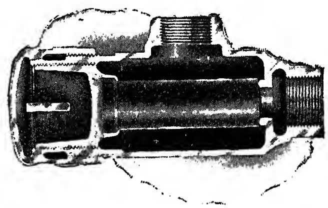


FIG. 25. DIAMOND TRAP.

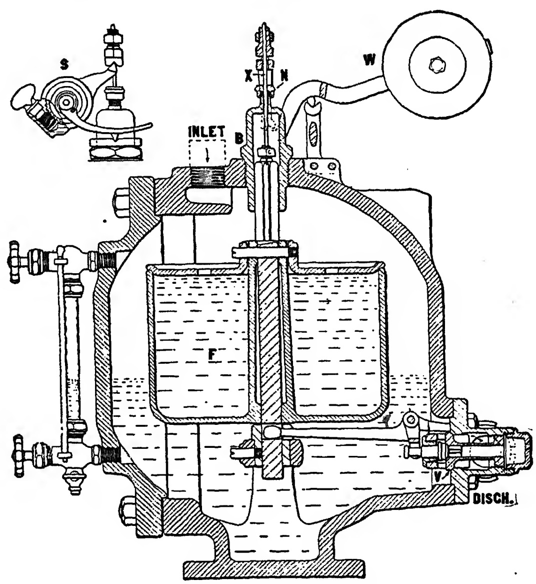


FIG. 26. SCHUTTE STEAM TRAP.

In large steam power plants the steam trap shown in Fig. 26 which is built by the Schutte and Koerting Co., is extensively used: The discharge valve *V* is balanced. The float is a tank *F* full of water and its weight is balanced on the outside by lever and weight *W*. The displacement of water outside the tank float causes the float to rise or fall and thus regulates the discharge valve *V* for continuous discharge. The connection between float and balance outside is effected through a wire *X* attached to the guide stem by a clamp nut.

The packing around the wire is not a stuffing box, but contains a thread of wool for preventing whistling, when air escapes.

This nut should never be tightened. The removal of the guide box *B* on top exposes the clamp nut, which secures the wire, and it can then be adjusted. The discharge valve complete with lever can be removed for examination by removing nuts and uncoupling the union of the outlet.

CHAPTER II.

STEAM AND WATER POWER.

Boilers. The boiler is the initial source of steam power and while not so conspicuous as the engine, is quite as important and should be selected with greatest care for life and property, as well as the economy of operation, are dependent upon its design and construction. Hence, when buying a boiler the quality must first of all be considered and then the price.

The designs of various boilers are too well known to require detailed descriptions in this book.

For the matter of completeness however a tubular boiler is illustrated in Fig. 27 and a water tube boiler in Fig. 28. In the tubular boiler the gases from the fire pass through the tubes, while in the water tube boiler the gases travel around the tubes. In the tubular boiler the water surrounds the tubes, whereas in the water tube boiler the tubes are filled with water.

The following data regarding boilers, feed water, and the method of determining the moisture in steam, are taken from the book entitled "Steam," published by the Babcock and Wilcox Company.

The requirements of a perfect steam boiler are:

1. Proper workmanship and simple construction, the materials which experience has shown to be the best being used, so as to avoid the necessity of early repairs.

2. A mud-drum in a place removed from the action of the fire to receive all impurities deposited from the water.

3. A steam and water capacity sufficient to prevent any fluctuation in pressure or water level.

4. A sufficient water surface for the disengagement of the steam from the water in order to prevent foaming.

5. A constant and thorough circulation of water throughout the boiler, so as to maintain all parts at one temperature.

6. The water space divided into sections, so arranged that, should any section give out, no general explosion can occur, and the destructive effects will be confined to the simple escape of the con-

tents, with large and free passages between the different sections to equalize the water line and pressure in all.

7. A great excess of strength over any legitimate strain; the boiler being so constructed as not to be liable to be strained by un-

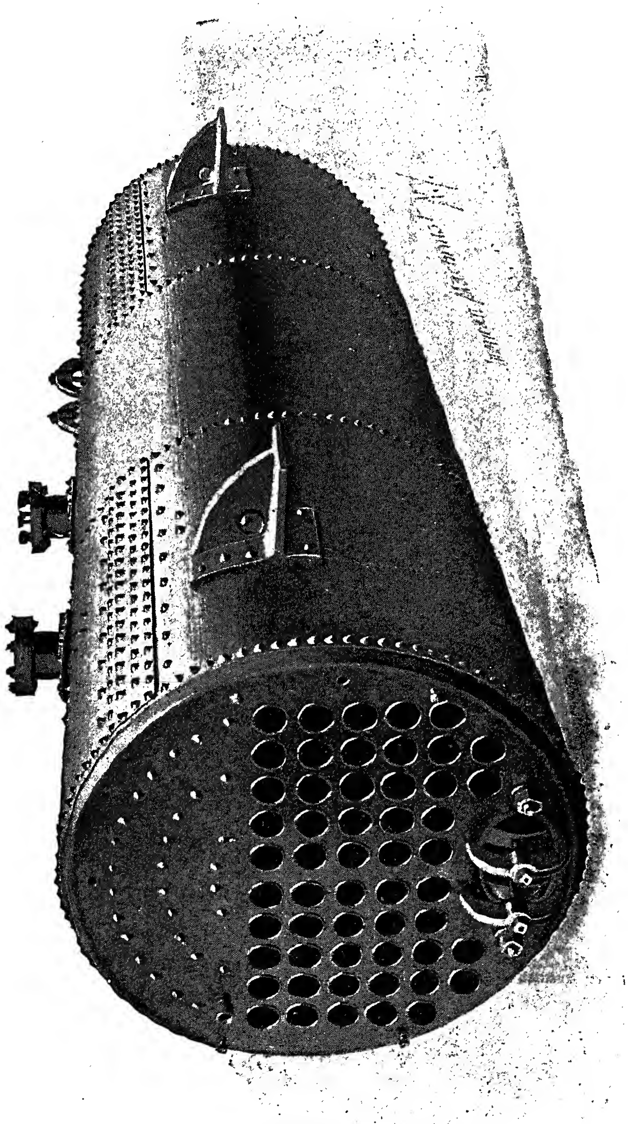


FIG. 27. TUBULAR BOILER.

equal expansion, and if possible, no joints exposed to the direct action of the fire.

8. A combustion chamber so arranged that the combustion of the gases commenced in the furnace may be completed before the escape to the chimney.

9. The heating surface as nearly as possible at right angles to the currents of heated gases, and so as to break up the currents and extract the entire available heat therefrom.

10. All parts readily accessible for cleaning and repairs. This is a point of the greatest importance as regards safety and economy.

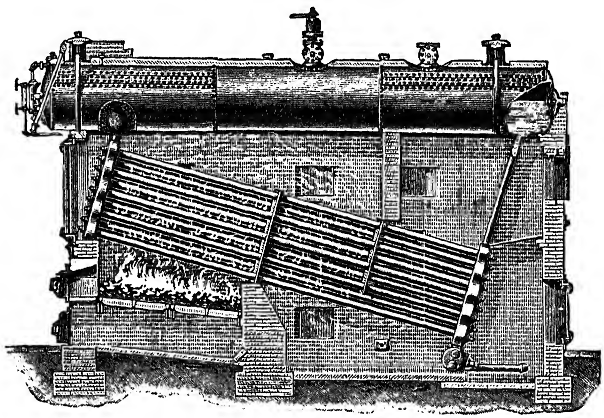


FIG. 28. WATERTUBE BOILER.

11. Proportioned for the work to be done, and capable of working to its full rated capacity with the highest economy.

12. The very best gauges, safety valves and other fixtures.

As to the care of boilers the following rules should be considered:

ATTENTION NECESSARY TO SECURE SAFETY.

1. **Safety Valves.** Great care should be exercised to see that these valves are ample in size and in working order. Overloading or neglect frequently leads to the most disastrous results. Safety valves should be tried at least once every day to see that they will act freely.

2. **Pressure Gauge.** The steam gauge should stand at zero when the pressure is off, and it should show the same pressure as the safety valve when that is blowing off. If not, then one is wrong, and the gauge should be tested by comparing it with one known to be correct.

3. **Water Level.** The first duty of an engineer before starting or at the beginning of his work is to see that the water is at the proper height; the only reliable way to do this is by trying the gauge cocks. If they do not agree with the water gauge the cause is to be learned and corrected.

4. **Gauge cocks** and water gauges must be kept clean. Water gauge should be blown out frequently and the glasses and passages to gauge kept clean.

5. **Feed Pump or Injector.** These should be kept in order and be of ample size. No make of pump can be expected to be reliable without regular and careful attention. It is always safe to have two means of feeding a boiler. Check valves and self-acting feed valves should be frequently examined and cleaned.

6. **Low Water.** In case of low water the fire has to be covered immediately with ashes (wet if possible) or any earth that may be at hand. Draw the fire as soon as this can be done without increasing the heat. Neither turn on the feed, start or stop engine, nor lift the safety valve until fires are out and the boiler cooled down.

7. **Blisters and Cracks.** These are liable to occur in the best plate iron or steel. When the first indication appears there must be no delay in making a careful examination and in removing the defective piece.

8. **Fusible plugs,** when used, must be examined when the boiler is clean, and carefully scraped clean on both the water and fire sides, or they are liable not to act.

Attention Necessary to Secure Economy.

9. **Firing.** Fire even and regularly, a little at a time. Moderately thick fires are most economical, but thin firing must be used where the draft is poor. The grates have to be kept evenly covered and no air holes are to be allowed in the fire; the fires are not to be cleaned oftener than necessary. With bituminous coal, a "coking fire," *i. e.*, firing in front and shoving back when coked, sometimes gives best results.

10. **Cleaning.** All heating surfaces must be kept clean outside and in, or there will be a serious waste of fuel. The frequency of cleaning will depend on the nature of fuel or water. As a rule, never allow over one sixteenth inch scale or soot to collect on sur-

faces. Hand holes should be frequently removed and surfaces examined, particularly in case of a new boiler, until proper cleaning intervals have been established by experience.

11. **Hot Feed Water.** Cold water should never be fed into any boiler when it can be avoided, but when necessary it should be caused to mix with the heated water before coming in contact with any portion of the boiler.

12. **Foaming.** When foaming occurs in a boiler, checking the outflow of steam will usually stop it. If caused by dirty water it can be remedied by blowing down and pumping up. In cases of violent foaming, check the draft and fires.

13. **Air Leaks.** All openings for admission of air to the boiler or flues, except through the fire, should be carefully stopped. This is frequently an unsuspected cause of serious waste.

14. **Blowing Off.** If the feed water is muddy or salty, blow off a portion frequently, according to condition of water. Empty the boiler every week or two, and fill up afresh. When surface blow-cocks are used, they should be often opened for a few minutes at a time. Make sure that no water is escaping from the blow-off cock when it is supposed to be closed. Blow-off cocks and check valves should be examined every time the boiler is clean.

Attention Necessary to Secure Durability.

15. **Leaks.** When leaks are discovered, they should be repaired as soon as possible.

16. **Blowing Off.** Never empty the boiler while the brickwork is hot.

17. **Filling Up.** Never pump cold water into a hot boiler. Many times leaks and, in shell boilers, serious weaknesses, and sometimes explosions are the result of such an action.

18. **Dampness.** Care has to be taken that no water comes in contact with the exterior of the boiler, as it tends to corrode and weaken the boiler.

19. **Galvanic Action.** Examine frequently parts in contact with copper or brass, where water is present, for signs of corrosion. If the water is salty or acid, some metallic zinc placed in the boiler will usually prevent corrosion, but it will need attention and renewal from time to time.

20. **Rapid Firing.** In boilers with thick plates or seams exposed

to the fire, steam should be raised slowly, and rapid or intense firing avoided. With thin water tubes, however, and adequate water circulation, no damage can come from this cause.

21. **Standing Unused.** If a boiler is not required for some time empty and dry it thoroughly. If this is impracticable, fill it quite full of water, and put in a quantity of common washing soda. External parts exposed to dampness should receive a coating of linseed oil.

22. **General Cleanliness.** All things about the boiler room should be kept clean and in good order. Negligence tends to waste and decay.

Heating Feed Water. The feed water furnished to steam boilers has to be heated from the normal temperature to that of the steam before evaporation can commence, and this generally at the expense of the fuel which should be utilized in making steam. This temperature at 75 lb. pressure is 320° F., and if we take 60° as the average temperature of feed, we have 260 units of heat per pound which, as it takes 1.151 units to evaporate a pound from 60°, represents 22.5 per cent of the fuels. All of this heat, therefore, which can be imparted to the feed water is just so much saved, not only in cost of fuel, but in capacity of boiler. But it is essential that it be done by heat which would otherwise be wasted. All heat imparted to feed water by injectors and "live steam heaters" comes from the fuel and represents no saving.

There are two sources of waste heat available: exhaust steam and chimney gases. By the former, water may be heated to 200° or possibly to 210°, in a well-proportioned heater. The feed water is generally forced

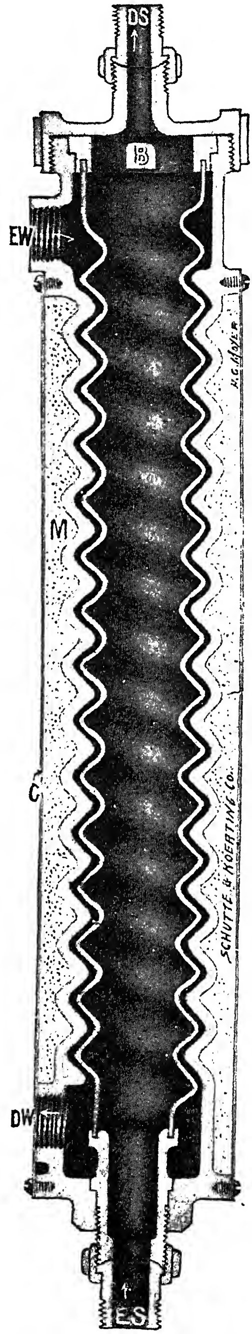


Fig. 29. Tube Heater.

through these heaters into the boiler by a pump or injector and is heated in passing, by contact with small tubes arranged in the interior of the heater, through which the exhaust steam from the engine passes. An excellent tube heater, which can be easily cleaned, having an extraordinarily large heating surface, is built by the Schutte and Koerting Co. (Fig. 29)

The gases going to the chimney carry off a large quantity of heat. This may be reduced materially by using a good boiler and by careful firing, but is always a considerable item. Some proportion of this heat is available for heating the feed water, by what are known as economizers, and frequently it may be carried nearly to the temperature of high pressure steam, making a saving in some instances of 20 per cent. The more wasteful the boiler, the greater the benefit of the economizer: but for large plants it is always a

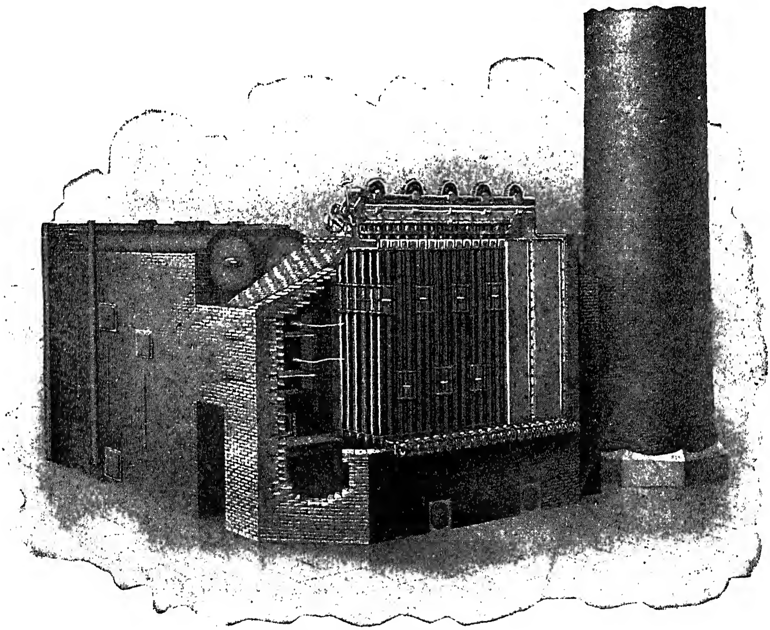


Fig. 30. Fuel Economizer.

valuable adjunct. In many cases water heated by exhaust steam may be still further heated in an economizer to advantage.

The standard Green fuel economizer, Fig. 30, which is widely used, consists of vertical cast-iron tubes about $4\frac{5}{8}$ inches in external diameter and 9 feet in length, made up in sets or sections of various

numbers of tubes to fill out any width and pressed into top and bottom headers. These sections again are assembled side by side to any length desired and connected with top and bottom branches or access pipes running lengthwise, one at a lower corner of the section where the water enters and the other at the diagonally opposite upper corner where the water leaves. Both access pipes are outside the brick chamber which encloses the economizer sections. The waste gases are led to one end of the economizer by the ordinary flue and escape from the opposite end to the chimney or mechanical draft fan. The feed water is usually forced by a pump or injector into the economizer through the lower branch pipe, entering at the end of the economizer where the gases leave and emerging from the upper branch pipe at the end of the economizer where the hot gases enter. The exterior of each tube is kept clean of soot by scrapers which travel continually up and down at a low rate of speed. The economizer is ordinarily fitted with blow-off and safety valves, and thermometers should be placed in the inlet and outlet pipes. A space is provided at the bottom of the chamber for the reception of the soot which falls from the scrapers. Dampers and by-passes are usually so arranged that the boiler plant can always be operated even though the economizer be out of commission.

Superheated Steam. Steam which has a higher temperature than that corresponding to its pressure is termed "superheated" or "gaseous" steam.

The greatest source of waste in an engine is through the condensation of steam by the cooling effect of the cylinder walls, or through what is called cylinder condensation. It has been established by practical tests that in ordinary single cylinder non-condensing engines using saturated steam, the amount of waste through cylinder condensation, with an early cut-off, is from 35 to 40 per cent. of the total steam used.

The best means of partially or wholly preventing this loss is by the use of superheated steam.

The gain through the use of superheated steam is due not only to the prevention of loss through condensation in steam pipes, but the addition of a certain amount of heat in the steam in the form of superheat, before it enters the cylinder, will make up for that robbed by the cylinder walls, and cause the steam to remain practically dry, at all events up to the point of cut-off.

The principles on which a superheater should be constructed are as follows:

1. It is necessary to place the superheater in a position where a suitable temperature is available. If a boiler is working under economical conditions, the difference between the temperature of the saturated steam generated by the boiler and of the escaping flue gases leaving a boiler is not sufficient to superheat the steam to even a moderate degree, unless the surface of the superheater is very large. Hence, generally speaking, a superheater should not be placed in the flue between boiler and chimney. On the other hand, if placed too near to the boiler furnace, excessive temperatures may be attained which would cause damage.

2. The superheater should be constructed to admit of all its parts expanding and contracting freely, without severe strains being put on any of the joints, which might cause them to leak; flange joints exposed to furnace gases should be avoided.

3. Provision should be made to protect the superheater against overheating when steam is not passing through it rapidly enough to carry away the heat supplied by the furnace gases.

The superheater shown in Fig. 31, which is built by the Babcock & Wilcox Co., fulfils these requirements. It is not subject to the immediate action of the fires, as before the furnace gases strike it they must pass through the front part of the boiler, and thereby come in contact with a considerable area of heating surface. Assuming the boiler to be used in regular work, and the firing even, no great fluctuations in temperature can take place in the amount of superheat. Moreover, all parts of the superheater are readily accessible for examination, and if necessary the tubes may be renewed. A record extending over many years of service has, however, demonstrated that the superheater requires practically no repairs.

There are no flanged joints; all the tube joints are expanded. Freedom for expansion is provided for by the tubes being free at one end, and by the manifolds not being rigidly connected with each other.

Overheating during steam raising is prevented by an arrangement for flooding with boiler water, and using the superheater as part of the boiler heating surface, while steam is being raised.

The tubes of the superheater are bent into U shape, and connected at both ends with manifolds, one of which receives the

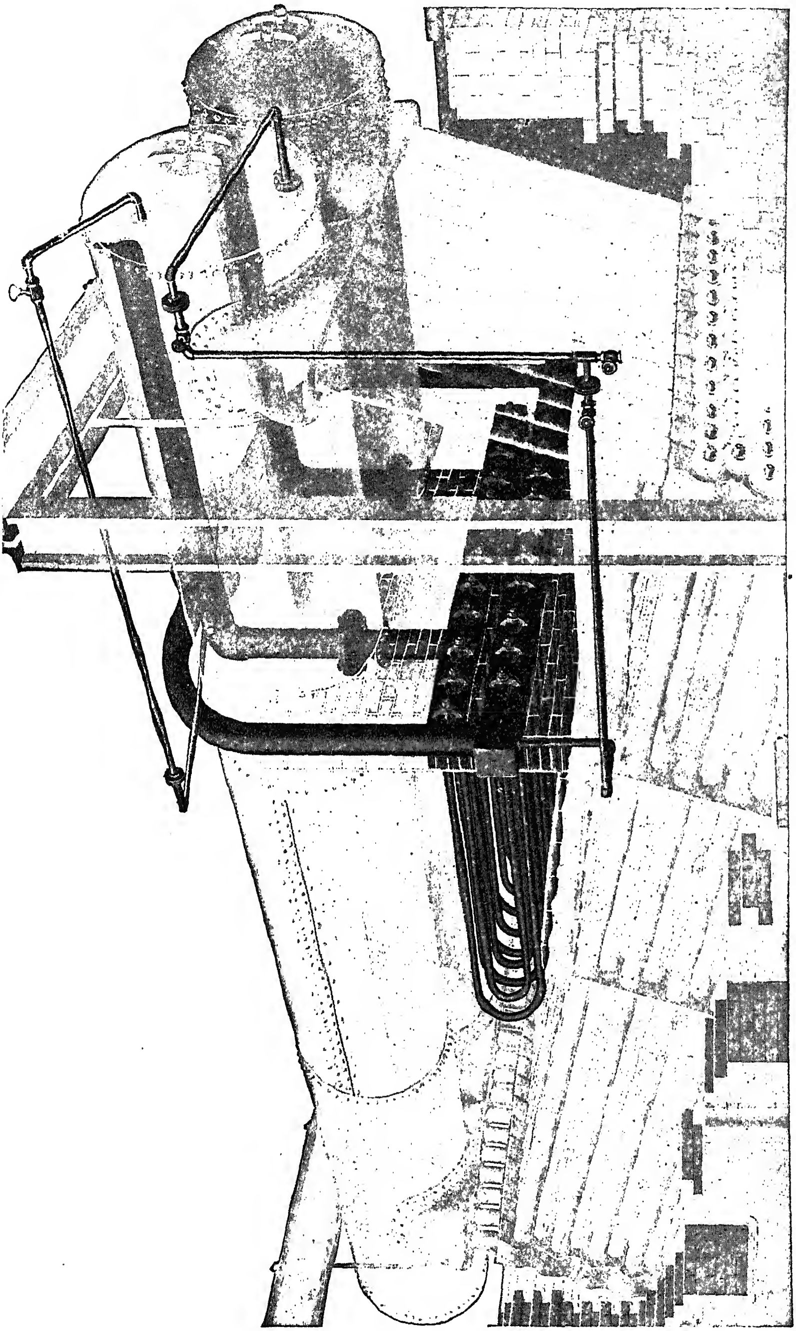


FIG. 31. BABCOCK WILCOX SUPERHEATER.

saturated steam from the boiler, the other collecting the superheated steam after it has traversed the superheater tubes, and delivering it to the valve, placed above the boiler.

The flooding arrangement consists simply of a connection with the water space of the boiler drum, and a valve by which, at the will of the operator, the water may be made to enter the lower manifold and fill the superheater to the boiler water level. Any steam formed in the superheater tubes is returned into the boiler drum, through the collecting pipe, which, when the superheater is at work, conveys saturated steam into the upper manifold. Prior

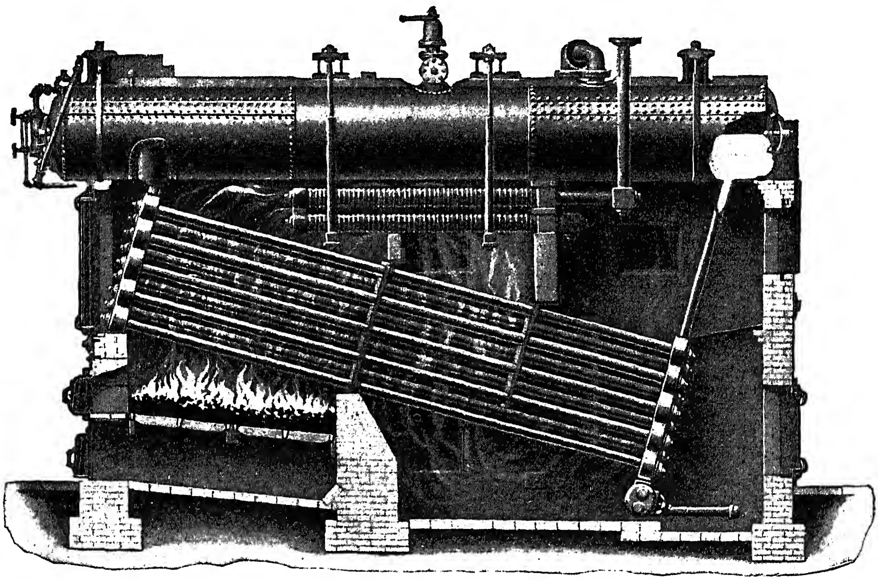


FIG. 32. FOSTER SUPERHEATER.

to opening the superheater stop valve and using superheated steam, the water is drained away from the manifolds by the flooding pipe.

A great number of these superheaters are now in active service, and experience has shown that they are both durable and efficient.

From 100° to 150° F. of superheat is usually provided for and it has been found by experiment that even with the most refined triple expansion engines, working under ordinary conditions, an economy of from 10 to 15 per cent. can be regularly obtained. With engines of lower economy, or of slower piston speed, the percentage of saving is usually greater.

Fig. 32 shows a Foster superheater, built by the Power Specialty Co.; Fig. 33 an independent superheater of this type.

Professor R. H. Thurston in a recent paper before the American Society of Mechanical Engineers on "Superheated Steam," arrives at the following conclusions:

1. Superheated steam, as hitherto employed in the steam engine, has absolutely no thermodynamic value; that is, it neither raises the upper limit of temperature or depresses the lower limit.

2. Superheating has for its whole purpose and result, in the steam engine to-day, the extinction or reduction of the internal thermal wastes of the engine, consequent upon the phenomenon known as initial or "cylinder condensation." Here it is extraordinarily effective, and a small quantity of heat expended in superheating the entering steam effects a comparatively large reduction in the expenditure of steam in the engine.

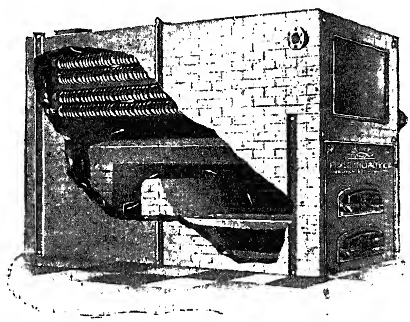


FIG. 33. INDEPENDENT FOSTER SUPERHEATER.

3. Superheating is superior to any other known means of reduction of internal waste.

4. No trouble need now be found at the engine with sufficient superheating under usual conditions of operation, to annihilate cylinder condensation.

5. The more wasteful the engine, the larger the promise of gain by superheating, and small engines will profit by it more than large, slow engines more than fast, and single engines more than multiple cylinder systems.

6. The larger the waste to be checked in the engine, the farther should the superheating be carried.

Incrustation and Scale. The presence of scale or sediment in a boiler results in loss of fuel, burning and cracking of the boiler, predisposes to explosion, and leads to extensive repairs. The most common and important substances in boiler scale are carbonate of lime, sulphate of lime, and carbonate of magnesia. Small amounts of alumina and silica are sometimes found and oxide of iron not infrequently is present as a coloring matter.

It is absolutely essential to the successful use of any boiler that it be accessible for the removal of scale, for though a rapid circulation of water will delay the deposit and certain chemicals will change its character, yet the most certain cure is periodical inspection and mechanical cleaning. This may, however, be rendered less frequently necessary, and the use of very bad water more practical, by the employment of some preventives. The following are a fair sample of those in use, with their results:

Oak, hemlock, and other barks and woods, sumac, catechu, logwood, etc., are effective in waters containing carbonates of lime or magnesia, by reason of their tannic acid, but are injurious to the iron, and not to be recommended.

Molasses, cane juice, vinegar, etc., have been used with success so far as scale is concerned, by reason of the acid which they contain, but this is even more injurious to the iron than tannic acid, while the organic matter forms a scale with sulphate of lime when it is present.

Milk of lime and metallic zinc have been used with success in treating waters charged with bicarbonate of lime, before they are used for feeding, reducing the bicarbonate to the insoluble carbonate.

Barium chloride and milk of lime are said to be used with good effect at Krupp's works, in Prussia, for waters impregnated with gypsum.

Soda ash and other alkalies are very useful in waters containing sulphate of lime, by converting it into a carbonate, and so forming a soft scale easily cleaned. But when used in excess they cause foaming, particularly where there is oil coming from the engine, with which they form soap. All soapy substances are objectionable for the same reason.

Petroleum has been much used of late years. It acts best in waters in which sulphate of lime predominates. As crude petroleum, however, sometimes helps in forming a very injurious crust, the refined only should be used.

Tannate of soda is a good preparation for general use, but in waters containing much sulphate, it should be supplemented by a portion of carbonate of soda or soda ash.

A decoction from the leaves of the eucalyptus is found to work well in some waters, in California.

For muddy water, particularly if it contain salts of lime, no pre-

ventive of incrustation will prevail except filtration, and in almost every instance the use of a filter, either alone or in connection with some means of precipitating the solid matter from solution, will be found very desirable.

In all cases where impure or hard waters are used, frequent "blowing" from the mud-drum is necessary to carry off the accumulated matter, which if allowed to remain would form scale.

When boilers are coated with a hard scale difficult to remove, it will be found that the addition of one fourth of a pound caustic soda per horse-power, and steaming for some hours, according to the thickness of the scale, just before cleaning, will greatly facilitate that operation, rendering the scale soft and loose. This should be done, if possible, when the boilers are not otherwise in use.

Tests for Moisture. In boiler trials it is essential to know the quality of the steam generated: whether it is wet, dry, or superheated. For many years the standard apparatus for ascertaining this was the barrel calorimeter, but this was superseded by the throttling calorimeter, an instrument first devised by Professor C. H. Peabody, of the Massachusetts Institute of Technology (see *Journal of Franklin Institute,* August, 1888), and which, when properly handled and connected, gives results far more accurate than can be obtained in any other way.

There have been numerous forms of this instrument, one of the simplest being that designed by Mr. George H. Barrus, of Boston, which is described below:

Steam is taken from a $\frac{1}{2}$-inch pipe provided with a valve and passes through two $\frac{3}{4}$-inch tees situated on opposite sides of a $\frac{3}{4}$-inch flange union, substantially as shown in the accompanying sketch (Fig. 34). A thermometer cup, or well, is screwed into each of these tees, and a piece of sheet iron perforated with a $\frac{1}{8}$-inch hole in the center is inserted between the flanges and made tight with rubber or asbestos gaskets, which also act as non-conductors of heat. For convenience a union is placed near the valve as shown, and the exhaust steam may be led away by a *short* $1\frac{1}{4}$-inch pipe, shown by dotted lines. The thermometer wells are filled with mercury or heavy cylinder oil, and the whole instrument from the steam main to the $1\frac{1}{4}$-pipe is well covered with hair felt.

Great care must be taken that the $\frac{1}{8}$-inch orifice does not become choked with dirt and that no leaks occur, especially at the sheet-

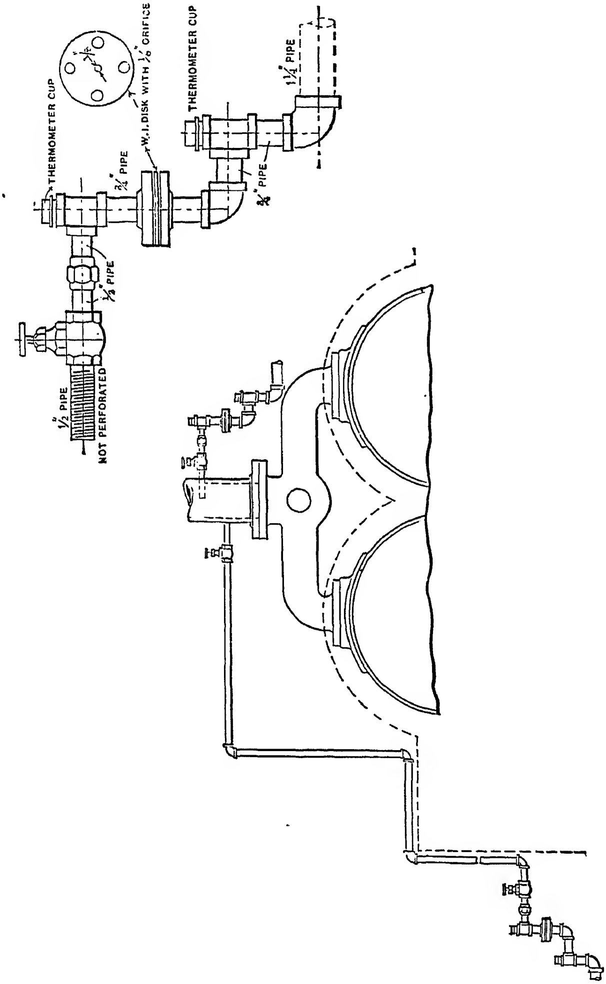


Fig. 34. Moisture Testing Apparatus.

iron disc, also that the exhaust pipe does not produce any back pressure below the flange. Place a thermometer in each cup, and, opening the ½-inch valve wide, let steam flow through the instrument for ten or fifteen minutes; then take frequent readings on the two thermometers and the boiler gauge, say at intervals of one minute.

The throttling calorimeter depends on the principle that dry steam when expanded from a higher to a lower pressure without doing external work becomes superheated, the amount of superheat de-

pending on the two pressures. If, however, some moisture be present in the steam, this must necessarily be first evaporated, and the superheating will be proportionately less. The limit of the instrument is reached when the moisture present is sufficient to prevent any superheating.

Assuming that there is no back pressure in the exhaust, and that there is no loss of heat in passing through the instrument, the total heat in the mixture of steam and moisture before throttling, and in the superheated steam after throttling, will be the same, and will be expressed by the equation

$$H - (xL/100) = 1146.6 + .48(t - 212)$$

or

$$x = [H - 1146.6 - .48(t - 212)]/L \times 100$$

in which x = percentage of moisture; H = total heat above 32° in the steam at boiler pressure; L = latent heat in the steam at boiler pressure; 1146.6 = total heat in the steam at atmospheric pressure; t = temperature shown by lower thermometer of calorimeter; 212 = temperature of dry steam at atmospheric pressure.

Theoretically the boiler pressure is indicated by the temperature of the upper thermometer, but owing to radiation, etc., it is usually too low, and it is better to use the readings of the boiler gauge, if correct, or better still to have a test gauge connected on the ½-inch pipe supplying the calorimeter.

If the instrument be well covered and there is as little radiating surface as possible, the above assumption that there is no loss of heat in passing through the instrument may be nearly, though never quite, correct. On the other hand, it is more than likely to be very far from correct, and, to eliminate any errors of this kind, Mr. Barrus recommends a so-called "calibration" for dry steam. This, again, involves an assumption which is open to some doubt, which is that steam, when in a quiescent state, drops all its moisture and becomes dry. No other practical method, however, has been proposed, and this is, therefore, the only method used at the present time. Some engineers, however, refuse to make any calibration, but, instead, make an assumed allowance for error.

To make the calibration, close the boiler stop valve, which must be on the steam pipe beyond the calorimeter connection. Keep the

steam pressure exactly the same as the average pressure during the test, for at least fifteen minutes, taking readings from the two thermometers during the last five minutes. The upper thermometer should read precisely the same as during the test, and the lower thermometer should show a higher temperature; this reading of the *lower* thermometer is the calibration reading for dry steam, which we will call T.

Calculation of results, allowing for radiation, by calibration method:

Formula $$x = [.48(T - t)/L] \times 100$$

in which x = percentage of moisture; T = calibration reading of lower thermometer; t = test reading of lower thermometer; L = latent heat of steam at boiler pressure.

The method of taking a sample of steam from the main is of the greatest importance, and more erroneous results are due to improper connections than to any other cause. The sample should be taken from the main steam current of the steam ascending in a vertical pipe. Avoid perforated and slotted nipples, and use only a plain, open ended nipple projecting far enough into the steam pipe to avoid collecting any condensation that may be on the sides of the pipe. Take care that no pockets exist in the steam main near the calorimeter in which condensation can collect and run down into sampling nipple. Make connections as short as possible.

As mentioned above, there is a limit in the range of the throttling calorimeter which varies from 2.88 per cent. at 50 pounds pressure to 7.17 per cent. at 250 pounds. When this limit is reached a small separator may be interposed between the steam main and the calorimeter, which will take out the excess of moisture. By weighing the drip from the separator and ascertaining its percentage of the steam flowing through and adding this to the percentage of moisture then shown by the throttling calorimeter, the total moisture in the steam may be ascertained. It is seldom, however, in a well designed boiler that any but a throttling calorimeter becomes necessary.

Boiler Tester. This apparatus is used for filling and testing boilers with hot water for pressures up to say three times to steam pressure. The instrument shown in Fig. 35, which is manufactured by the Schutte and Koerting Co., Philadelphia, is a combination of two machines, one of large capacity for rapidly filling the boiler and

a smaller one to overcome a high counter-pressure. After the boiler is filled the large machine *F* is shut off, and the small high-pressure machine *I* is started to apply the pressure.

This machine is made for a capacity only sufficient to make up for possible leaks in the boiler to be tested, and any excess above this is discharged through the automatic overflow safety valve *D*. This valve is loaded with a spring, which can be set to the desired

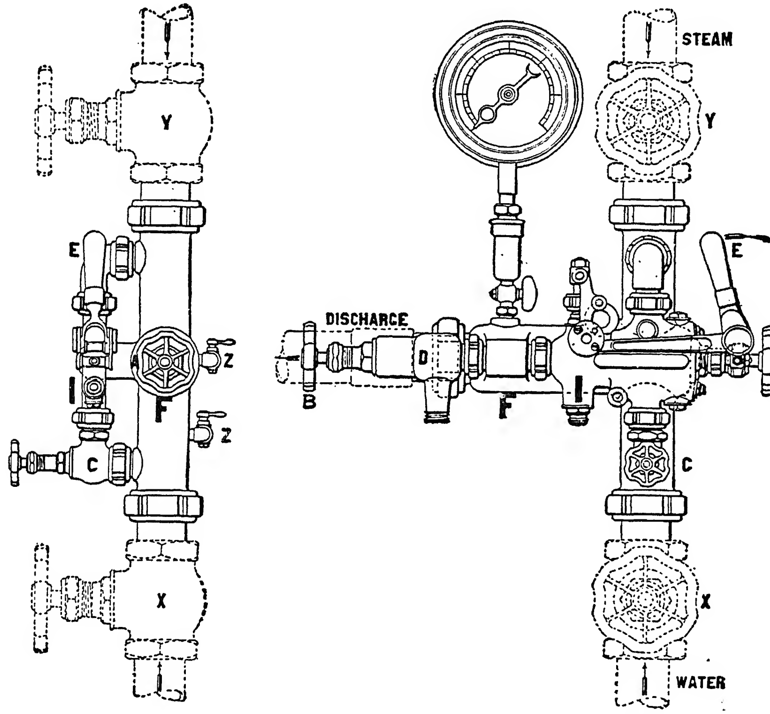


FIG. 35. BOILER TESTER (SIDE VIEW AND END VIEW).

pressure by the hand wheel *B*. It will then maintain the same pressure while the excess water discharges at the overflow. To fill the boiler valves *X* and *Y* are opened, valve *C* is closed tight and the steam valve *A* opened. To apply pressure, valve *A* is closed tight, water valve *C* is opened, and the injector *I* started with handle *E*. An air cock or opening must be left at the top of the boiler to be opened when boiler is filling and closed when full.

The boilers should be tested from time to time.

Water Purifiers and Filters. A heater and purifier combined, as

built by the Murray Iron Works, Burlington, Iowa, is shown in Fig. 36. In this purifier the feed water supply from the pump or tank is regulated by an automatic float valve which admits only as much water as the boiler requires. The feed water first passes

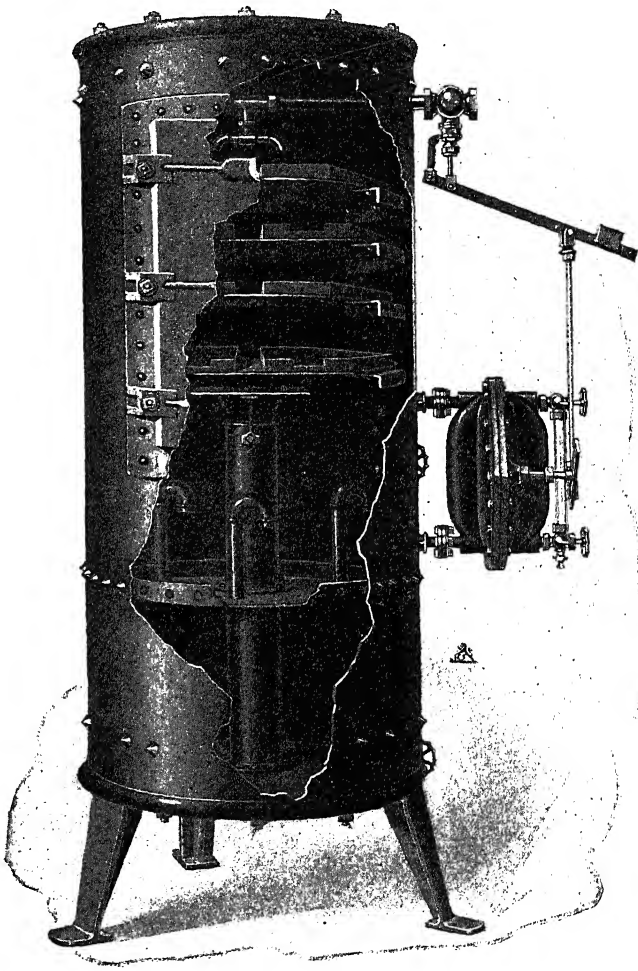


FIG. 36. WATER HEATER AND PURIFIER.

over a series of removable pans which take out such impurities as will precipitate at a temperature of 212 degrees, such as lime and magnesia, then to the settling chamber, where the oil and such impurities as come to the surface of boiling water are skimmed off; thence to the pure water or pump suction chamber, through a series

of syphon goose necks that take the pure water from beneath the surface in the settling chamber only; the syphoning being stopped by the admission of air into the goose necks, when the surface of the feed water is an inch above the openings in the goose necks, where it is kept hot by the exhaust steam pipe that passes through it.

Water filters, which are widely used in boiler plants, water works and other industries are built by the New York Continental Jewell Filtration Company, New York. Fig. 37 shows a small filter built by this firm having a capacity of about 400 gallons per hour. This type is operated by one valve only and revolving rakes are provided for breaking up the filter bed when washing.

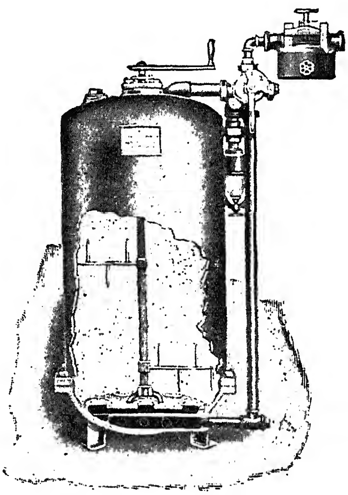


FIG. 37. WATER FILTER.

Figs. 38 and 39 show the New York sectional washing pressure filter. For filtering the valves should be set as follows: Open *A, B, G* and *H;* close *C, D, F* and *K,* turn *F* so that the index points to number *1* on wheel, and adjust *I* to feed sufficient alum solution to produce clear filtered water.

To wash the filter the following two steps have to be observed:

1. Close *G, H, A* and *B;* open *D* and *C,* and turn *F* so that the index points to number *2* on wheel; allow water to flow three or four minutes, then turn *F* so that the index points to number *4;* again allow water to flow three or four minutes, then turn *F* so that the index points to number *1,* and allow water to flow three or four minutes.

2. Close *D* and *C,* open *A, E, G* and *H* (the valve *I* having been adjusted to feed sufficient alum solution to produce clear filtered water); allow water to flow until clear (usually two or three minutes suffices), then close *E* and open *B.* This done, the washing is finished and filter is in service.

The directions for the coagulant tank are as follows:

To fill the coagulant tank, close *H* and *G,* remove plug cover *J* and open *K* to drain solution from tank, then close *K* and fill tank

with crystal alum; next open *H* fully and when water fills tank close *H* and replace plug cover *H*, then open *G* and *H* fully.

The coagulant tank connections being small require blowing out at least once a month; to do this, select time when tank requires filling and before removing plug cover *J*, open *H* and *K* fully; allow water to flow from drain pipe one half minute, then close *H* and open *J* and *I* fully; allow water to flow one half minute, then close

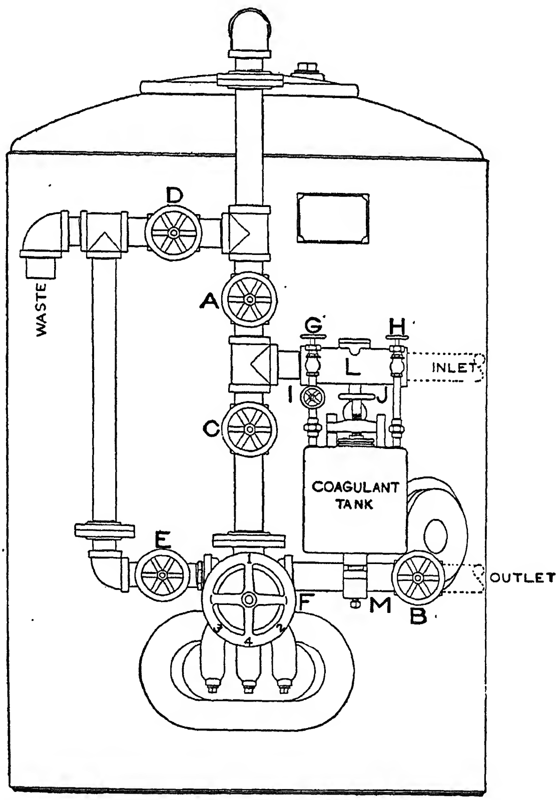


Fig. 38. Pressure Filter.

J and *K*, adjust *I* to normal position to feed sufficient alum solution to produce clear filtered water, and proceed as directed above to fill coagulant time.

The valve *L* is a back-pressure valve to insure a circulation of water through the coagulant tank. The amount of back pressure can be adjusted by means of the weights on the lever; raising the weight decreases the back pressure, and lowering the weight in-

creases the back pressure. The weight is adjusted before leaving the factory and rarely requires readjustment.

With this filter the results depend exclusively upon the care and regularity in washing. The filter should be washed once in every

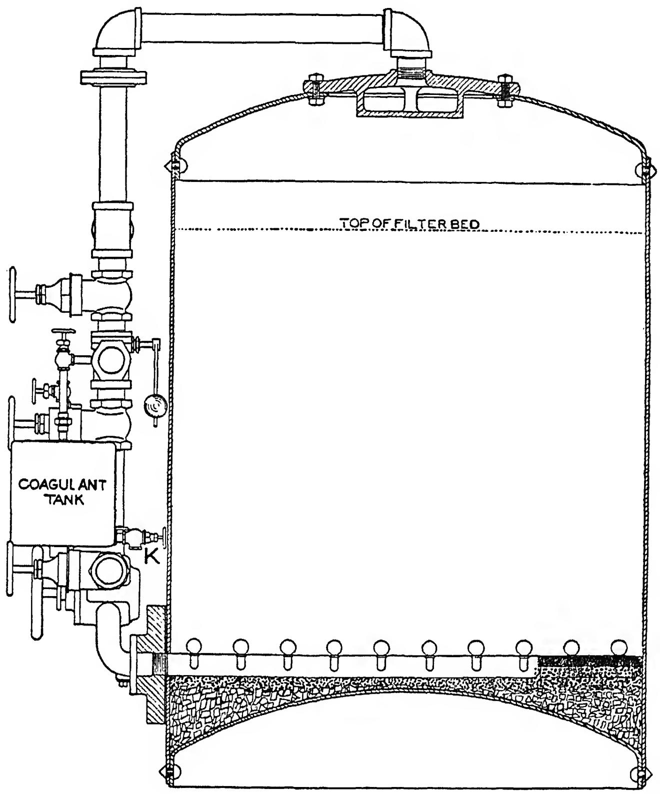


FIG. 39. PRESSURE FILTER.

twenty-four hours if in service. Only sufficient alum solution is to be used to produce clear filtered water. The coagulant tank should at all times contain alum.

Steam Engines. In classifying engines with regard to their general arrangement of parts and mode of working account has to be taken of a considerable number of independent characteristics. We have, first, a general division into condensing and non-condensing engines, with a subdivision of the condensing class into those which act by surface condensation and those which use injection. Next there is the division into compound and non-compound, with a

further classification of the former as double, triple or quadruple expansion engines. Again engines may be classed as single or double acting, according as to steam acts on one or alternately on both sides of the piston. Again a few engines—such as steam hammers and certain kinds of steam pumps—are non-rotative, that is to say, the reciprocating motion of the piston does work simply on a reciprocating piece; but generally an engine works on continuously revolving shaft, and is termed rotative. In most cases the crank pin of the revolving shaft is connected directly with the piston rod by a connecting rod, and the engine is then said to be direct-acting; in other cases, of which the ordinary beam engine is the most important example, a lever is interposed between the piston and the connecting rod. The same distinction applies to non-rotating pumping engines, in some of which the piston acts directly on the pump rod, while the others act through a beam. The position of the cylinder is another element of classification, giving horizontal vertical and inclined cylinder engines.

No type of steam engine is so common as the horizontal direct-acting. We give the details of construction generally followed in this class of engine.

The cylinder consists of cast iron, exactly bored, of which the ports and sides of the valve chest form part. Sometimes there is an interior cylinder called a " liner," especially in large engines, and the space between the inner and outer cylinder is used as a steam jacket. In the front cylinder cover there is a stuffing box through which the piston rod passes. The stuffing box is kept steam-tight by a soft packing which is pressed in by a gland. In some instances the packing consists of metallic rings. The cylinder cover and gland are lined with a brass ring in the hole, through which the piston rod passes. The valve rod is brought out of the valve chest in the same way. The piston is a hollow casting into which the piston rod is screwed and riveted over. It is packed by two split rings of cast iron, which are sprung into recesses turned into the circumference of the piston. This mode of packing is used in locomotives and small engines. For large pistons the usual plan is to employ wider split rings, called floating rings, pressed against the sides of the cylinder, not by their own elasticity, but by separate springs behind them in the body of the piston; they are held in place by a movable flange, called a junk ring, on one face of the piston.

The cross-head consists of a steel centerpiece with a round boss, in which the piston rod is secured by a cotter and a forked front, where the end of a connecting rod works on a pin. A pair of pins at top and bottom carry the steel shoes or sliding blocks, whose distance from the center is adjustable by nuts to take up wear. Occasionally the crank is omitted, and the connecting rod works on a pin fixed in a disk on the end of the shaft on the main bearing. The valve rod, which is worked by an eccentric just behind the bearing, is extended through the end of the valve chest, and forms the plunger of a feed pump which is bolted to the end of the chest. Frequently the feed pump is fixed at any convenient part of the bed-plate, and is driven by a separate eccentric, and in some cases its plunger is connected directly to the cross-head. In the main bearing the shaft turns in gun metal or phosphor-bronze blocks called bearings. In heavy engines these are generally lined with Babbitt's anti-friction metal or other soft alloy, and in many modern engines the brasses are entirely dispensed with, a lining of Babbitt's metal being let into the cast-iron surface of bearing. When the bearings are in two pieces, the plane of division between them is chosen to be that in which the wear is likely to be the least. A more satisfactory adjustment is possible when the bearings are in three or more pieces.

In large engines the most usual plan of automatically regulating the expansion is to employ some form of trip gear, the earliest type of which was introduced by G. H. Corliss. In the Corliss system the valves which admit steam are distinct from the exhaust valves. The latter are opened and closed by a reciprocating piece, which takes its motion from an eccentric. The former are opened by a reciprocating piece, but are closed by springing back when released by a trip, or trigger action. The trip occurs earlier or later in the piston's stroke, according to the position of the governor. The admission valve is opened by the reciprocating piece with equal rapidity whether the cut-off is going to be early or late. It remains wide open during the admission, and then when the trip action comes into play, it closes suddenly. Generally the valves of Corliss engines are cylindrical plates turning in hollow cylindrical seats which extend across the width of the cylinder. Often, however, the admission valves are of the disc or double-beat type, and spring into their seats when the trip gear acts. Many forms of Corliss gear have been invented by Corliss himself and others.

In the large horizontal Corliss engine the cylinder is steam-jacketed around the barrel in the space between the liner and the outer cylinder, and also at the ends, which are cast hollow for this purpose. In large horizontal engines the weight of the piston tends to cause excessive wear on the lower side of the cylinder. In some of this type a part of the weight is borne by a tail rod, ending in a block, which slides on a fixed guide behind the cylinder. To further diminish wear the piston is sometimes made much wider and the device is sometimes resorted to of giving the piston rod an upward curvature in the middle portion, which the weight of the piston reduces to straightness.

When uniformity of driving effort or the absence of dead points is especially important, two independent cylinders are often coupled to the same shaft by cranks at right angles to each other, an arrangement which allows the engine to be started readily from any position. Winding engines in which ease of starting, stopping and reversing is essential, are very generally made by coupling a pair of horizontal cylinders, with cranks at right angles to each other, on opposite sides of the winding drum, with the link motion as the means of operating the valves.

For mill engines the compound tandem and compound coupled types are now the most usual, and the high-pressure cylinder is very generally fitted with Corliss gear. In the compound coupled arrangement the cylinders are on separate bed-plates, and the fly wheel is between the cranks.

The general arrangement of vertical engines differs little from that of horizontal engines.

Steam Turbines. As steam turbines are coming more and more into use because of the greater fuel economy in their operation as compared to steam engines, the description of a standard machine of this type, the "Parsons," will be of interest. Fig. 40 is the longitudinal section through a turbine of the Parsons type, showing the turbine in diagrammatic form, but omitting all details which are not necessary to an understanding of the general principles.

The turbine consists essentially of a fixed casing, or cylinder, and a revolving spindle, or drum. The ends of the spindle are extended in the form of a shaft, carried in two bearings *A* and *B*, and, excepting the small parts of a governing mechanism and the oil pump, these bearings are the only rubbing parts in the entire turbine.

Steam enters from the steam pipe at *C* and passes through the main throttle or regulating valve *D*, which, as actually constructed,

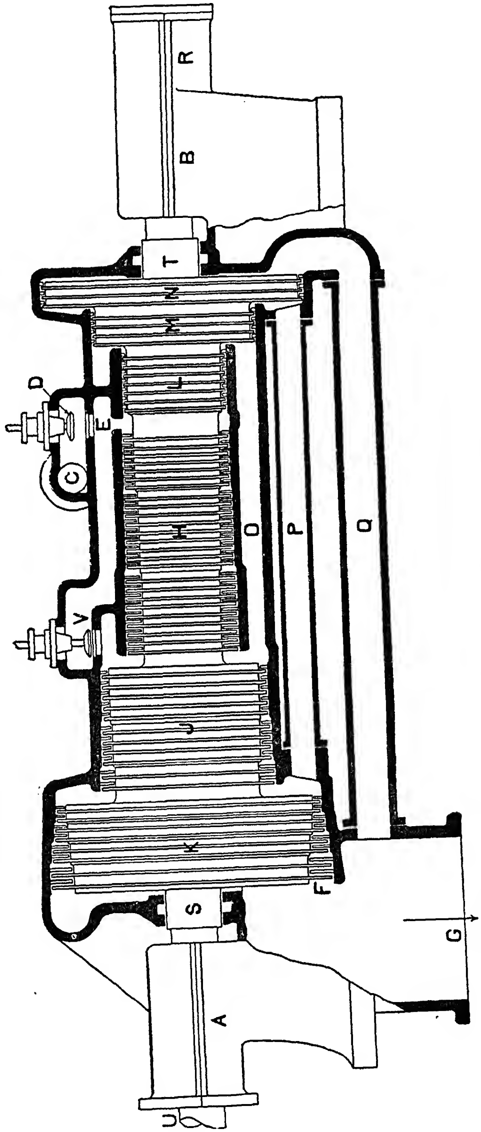


FIG. 40. STEAM TURBINE.

is a balanced valve; this valve being operated by the governor through suitable controlling mechanism.

The steam enters the cylinder through the passage *E*, and turning to the left (as seen in cut) passes through alternate stationary and

revolving rows of blades, finally emerging from the blades at *F* and passing through the passage *G* to the condenser or to the atmosphere, according to whether the turbine is condensing or non-condensing.

Each row of blades, stationary and revolving, extends completely around the turbine, the steam flowing through the full annulus between the spindle and the cylinder. In an ideal turbine the lengths of the blades and the diameter of the spindle which carries them would continuously and gradually increase from the steam inlet to the exhaust. Practically, however, the desired effect is produced by making the spindle in steps, there being generally three such steps or stages, *H, J* and *K*.

The blades in each step are arranged in groups of increasing length. At the beginning of each of the larger steps the blades are usually shorter than at the end of the preceding smaller step, the change being made in such a way that the correct relation of blade length to spindle diameter is secured.

The steam, acting as previously described, produces a thrust, tending to force the spindle towards the left, as seen in the cut. This thrust, however, is counteracted by the "balance pistons" *L, M* and *N,* which are of the necessary diameter to neutralize the thrust on the spindle steps *H, J* and *K* respectively. These elements are called "pistons" for convenience, although they do not come in contact with the cylinder, but both the pistons and the cylinder are provided with alternate rings which form a "labyrinth" packing to retort the leakage of steam. In order that each balance piston may have the proper pressure on both sides, equalizing passages *O, P* and *Q* are provided, connecting the balance pistons with the corresponding steps in the blading.

The end thrust being thus practically neutralized by means of the balance pistons, the spindle "floats" so that it can be easily moved in one direction or the other. In order to definitely fix the position of the spindle a small "thrust bearing" is provided at *R* inside the housing of the main bearing *B*. This so-called thrust bearing is adjustable, to locate and hold the spindle in such position that there will be such a clearance between the rings of the balanced piston, and those of the cylinder as will reduce the leakage of steam to a minimum and at the same time prevent actual contact under varying conditions of temperature.

Where the shaft passes out of the cylinder at *S* and *T* it is necessary to provide against in-leakage of air or out-leakage of steam. This is accomplished by means of glands which the small scale of the illustration prevents from showing as actually constructed. The shaft of the turbine is extended at *U* and coupled to the shaft of the electric generator by means of a flexible coupling inside of the bearing housing.

The turbines are so proportioned that, in using steam as previously described, they have just enough overload capacity to take care of the ordinary fluctuations of load when controlled by the governor through the valve *D*, thus insuring maximum economy of steam consumption at approximately the rated load. To provide for greater overloads, the valve *V* is supplied, to admit steam to intermediate stages of the turbine; this being the equivalent of the by-pass valve generally used for admitting live steam to the low-pressure cylinder of a compound reciprocating engine. This valve, shown diagrammatically in the illustration, is arranged to be operated by the governor or by hand, as the conditions under which the turbine is to work may require, and is, according to circumstances, located either as shown by the illustration, or at another stage of the turbine.

If it were possible to make the rotor of the steam turbine a tight working fit in its cylinder so as to prevent leakage of steam, the high steam economy of the turbine would even more nearly approach the theoretical limit. The high speeds which are essential in the steam turbine, however, preclude any continuous contact between the rotating and stationary parts, except in the well-lubricated bearings. The rubbing of other parts would produce such friction as would more than neutralize the increased steam economy, and result in the ripping out of blades.

It is necessary, therefore, to effect a compromise by leaving a clearance between the rotating and stationary parts and allowing the steam to leak through this clearance, but reducing this leakage to the minimum possible. For this reason the tips of the rotating blades just clear the cylinder and the tips of the stationary blades just clear the surface of the spindle. For the same reason the rings of the "labyrinth" packing of the balance pistons are not allowed to come into contact. The necessity of permitting a leakage of steam, and at the same time keeping such leakage as small as pos-

sible has an important bearing on the whole design of the turbine, both as to general proportions, mechanical details, and methods of construction.

Water Power. In some localities water power can be produced very economically, though in most cases it is advisable to have a steam or gas power plant as reserve.

A water wheel which is widely and successfully used is the Pelton wheel shown in Fig. 41. It consists of a cast-iron or steel center, to the periphery of which are attached cups or buckets. The wheel

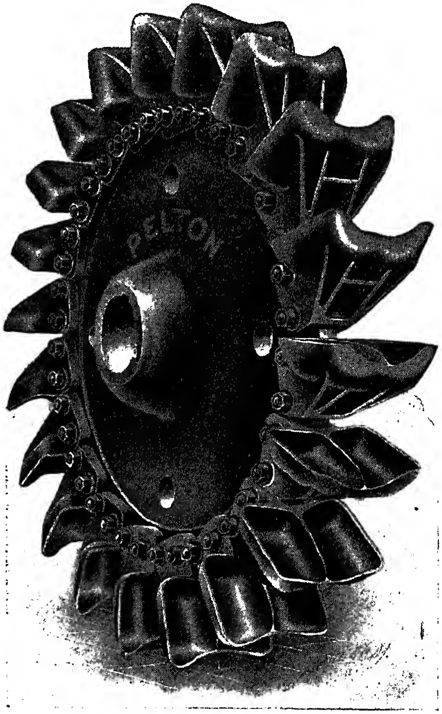


FIG. 41. WATER WHEEL.

is carried on a horizontal shaft, supported by journal boxes. The water, being led to the wheel by means of a pipe, impinges on the buckets through a nozzle, the end of which is fitted with a cylindrical tip of a diameter proportioned to the head of water and amount of power to be developed. Different diameters of tips can be screwed into the nozzle, thereby varying the power of the wheels from the maximum, which is limited by the size of the bucket, down

to a small proportion of the rated capacity; in this way no more water is used than is actually required for the power, and a uniformly high efficiency is maintained at all stages of load.

The power of a wheel does not depend on its diameter but upon the head and amount of the water applied to it—in other words, the size of nozzle used—which establishes the size of bucket on the wheel. The diameter of the wheel determines its speed, and, under a given head, the number of revolutions at which a certain size of wheel runs, should be constant, irrespective of the power developed.

Where a very considerable amount of power is required under a comparatively low head a wheel of large diameter is sometimes necessary to admit of buckets of proper size, as also the application of two or more nozzles, for the purpose of multiplying the power.

Under certain conditions of head and power turbine wheels are used in place of the water wheels.

CHAPTER III.

GAS POWER.

Gas Engines. On account of the higher efficiency of gas engines as compared to steam engines it is frequently of advantage, even though in chemical factories steam is always available, to use gas power. In connection with producer gas the combustion engines present the cheapest means of generating power, since in a gas producer an efficiency of 80 per cent., in a gas engine of 26 per cent. is easily obtained, so that by this system it is possible to generate one horse power per hour from less than one pound of coal.

While these gas engines are built both in vertical and horizontal type, we will describe below only a typical horizontal construction, the Koerting four-cycle engine, of which a longitudinal section is shown in Fig. 42.

Cycle. In the well-known Beau de Rochas or four-stroke cycle on which this engine operates, three strokes of the piston are employed for the purpose of expelling the burned gases, drawing in the fresh charge of combustible mixture of gas and air and, by forcing it under high pressure into the small space afforded by the combustion chamber, preparing it to do work on the succeeding or fourth stroke.

Expansion. In the illustration shown, the piston has advanced about half way on its power stroke. Ignition of the combustible charge effected by a special mechanism described below under that head, having taken place just before the crank passes the dead center, the high-pressure gas, expanding after having received the heat generated by its own combustion, transforms the heat into work, which, transmitted through the piston and connecting rod, turns the main engine shaft.

Exhaust. Just before the engine passes the outer dead center the exhaust valve shown at the bottom of the cylinder head is opened and the pressure at once drops to that of the atmosphere. This exhaust valve remains open during the return stroke and allows the burned gases to be expelled by the returning piston. The hot gases escaping through the valve opening are cooled by water sur-

rounding the valve housing and exhaust pipe, which reduces the back pressure and tends to silence the exhaust.

Fresh Charge. As the piston starts on its second out-stroke the exhaust valve is closed and the admission valve is opened, allowing

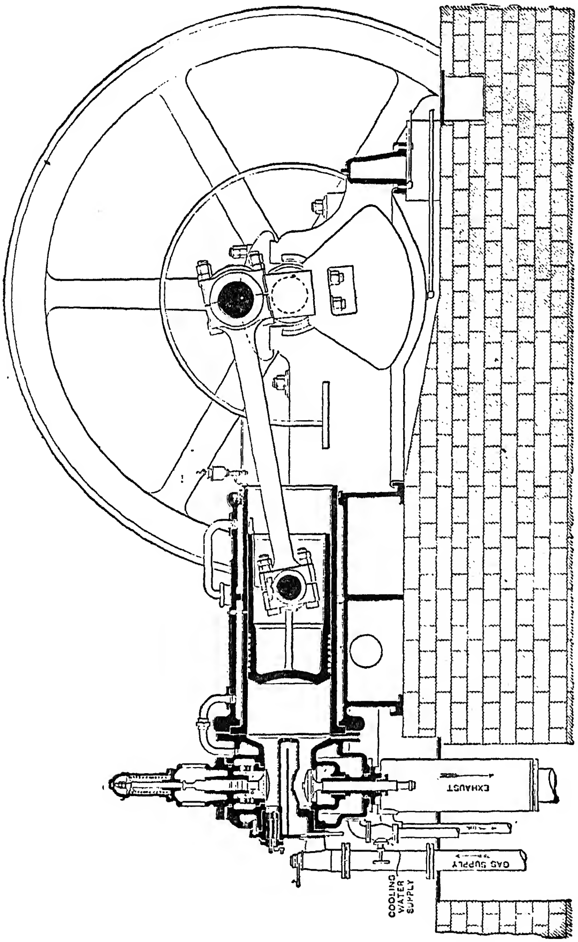


FIG. 42. LONGITUDINAL SECTION OF FOUR-CYCLE GAS ENGINE.

the piston to suck in a fresh charge of gas and air accurately proportioned—by passing through an outside set valve—to conform to the requirements of perfect combustion and maximum economy.

Compression. On the return stroke both the admission and the exhaust valve are closed, and the charge thus trapped in the cylinder is compressed by the returning piston to the volume of the clearance spaces afforded in the end of the cylinder and the combustion chamber.

During compression the temperature of the charge rises very rapidly and the limit at which the compressed charge will ignite from its own heat is soon reached.

Since in gas engine practice the economy attained depends upon the degree of compression of the charge prior to ignition, modern practice demands that compression be carried as high as this ignition temperature will admit.

Rich gases, or those containing large quantities of hydrogen and hydrocarbons, ignite at a lower temperature than "leaner" gases, in which the percentages of these constituents are lower. As the size of the engines increases the cylinder jacket becomes less effective in cooling the central part of the mass of mixture. The evil effect of these conditions, which tend to produce preignition, is kept within bounds by a new system of jackets, through which cold water is circulated. This reduces the temperature of the charge, so that the comparatively high compression, necessary to high economy, is made possible. In order, then, to employ rich gases to their best advantage in medium and large size engines, the Koerting engine is provided with a specially designed internal water jacket, the cooling surface of which may be increased to meet the demand made by gas of any composition working in an engine of any size. This device consists of a hollow water-cooled cover secured to the back of the cylinder head and projecting into the combustion chamber. By slightly changing the shape of this casting the cooling surface may be varied at will to suit any requirement. This simple device allows even the largest engines to enjoy the same high compression as is used in the smallest without fear of preignition.

The incoming gas having passed through a set regulating valve in the gas main is supplied to the mixing valve in the proper proportion to insure perfect combustion and consequent maximum efficiency.

Governing. The combustible complement of air and gas mixed according to the requirements of perfect combustion, before being admitted to the power cylinder, is made to pass a throttling valve, which determines the amount of fuel necessary to maintain the required speed for one complete cycle.

Ignition is effected by an oscillating electromagnet which insures a spark of uniform strength regardless of the speed of the engine.

The transverse section of a Koerting engine is shown in Fig. 43.

These engines are started by means of compressed air stored in a receiver.

For large units the four-cycle engines are built double acting, twin and tandem.

Oil Engines. As under certain local conditions these engines can be operated with very great economy a few words about their

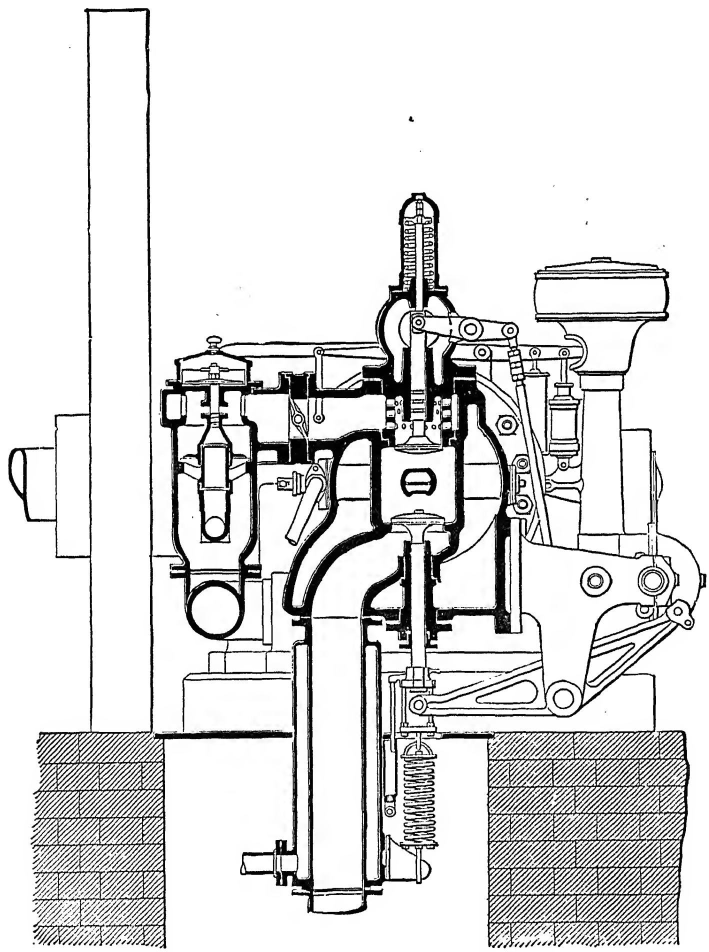


FIG. 43. TRANSVERSE SECTION OF FOUR-CYCLE GAS ENGINE.

construction will be of interest in this place. The main difference in the operation and construction of oil engines from gas engines is the fact that the oil before going into the cylinder has to be evaporated thereby necessitating the use of a suitable gasifier. An oil

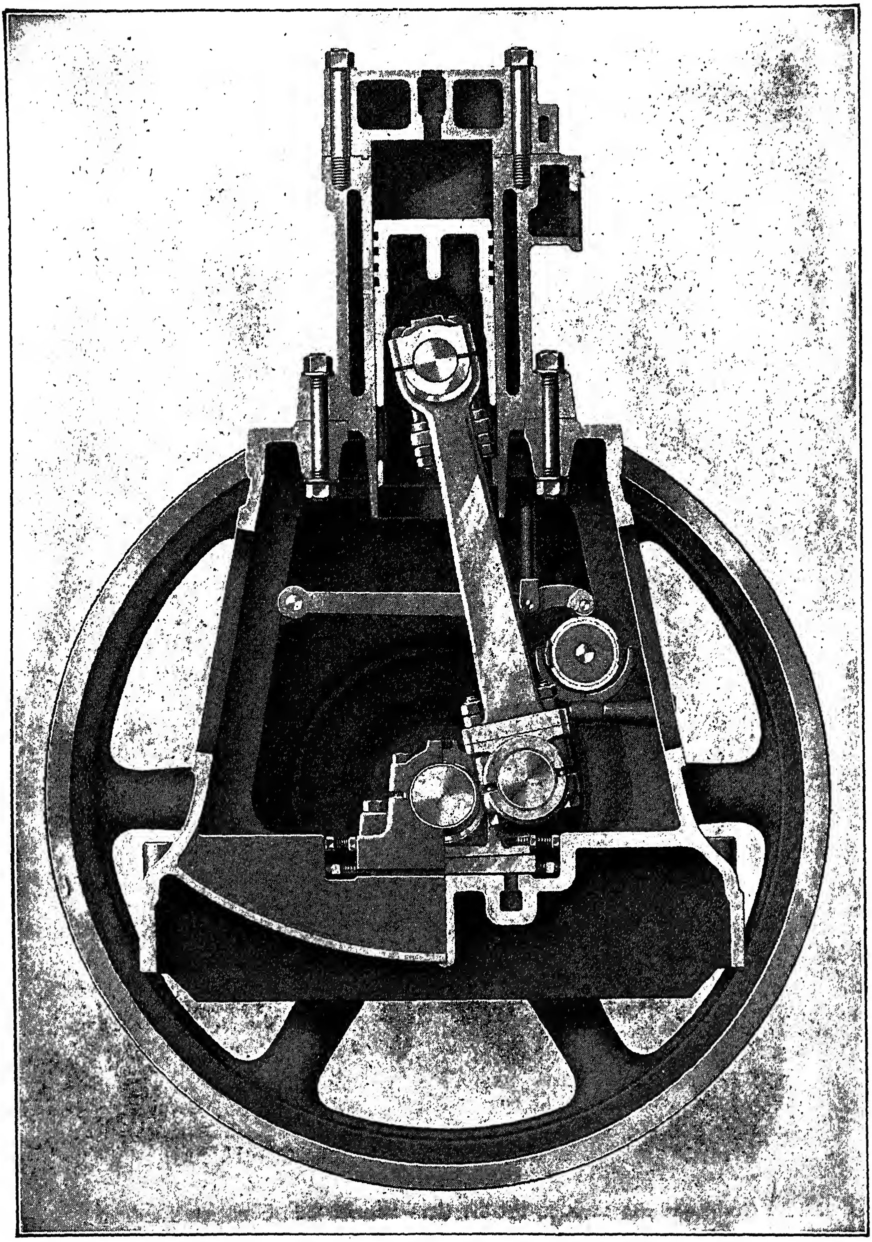


FIG. 44. DIESEL ENGINE.

engine of peculiar construction is the Diesel engine, in which the oil is ignited by highly compressed air without the use of an igniter. In this construction a perfect combustion is obtained and one horse power per hour is generated from one half pound of oil, while in all other oil engines about twice as much fuel is consumed. A Diesel engine is shown in Fig. 44.

Suction Producer. The type of producer which has been found to be the best adapted to small and medium size installations is known as the suction producer to distinguish it from the form in which the gas is supplied to the engine under a slight pressure, and which is more complicated on account of involving the use of gas-holders, boilers and much additional piping. In this form of pro-

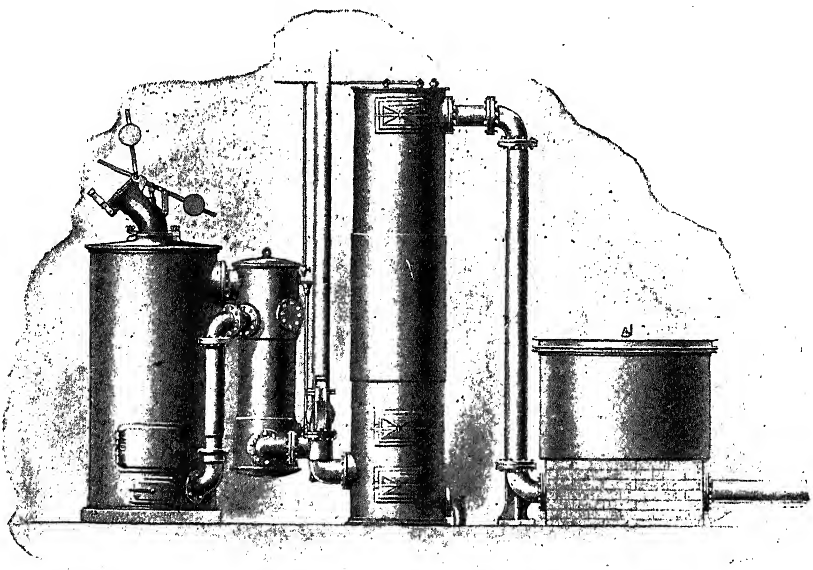


FIG. 45. GENERAL VIEW OF SUCTION PRODUCER.

ducer exterior atmospheric pressure is employed to force the combustible mixture of gas and air into the motor cylinder, a vacuum sufficient to overcome the resistance encountered by the gases in traversing the generating apparatus being produced by the action of the motor piston itself.

In engines working on suction producers, regulation is effected by means of a balanced valve inserted in the main gas supply line and actuated by the governor. This device not only controls the

operation of the engine, but also that of the producer. In running under light load the throttling device allows only a small amount of gas to enter the cylinder and the suction on the producer is light. When the load increases, however, the throttling is less marked and a greater amount of air is allowed to rush through the producer, effecting the generation of an increased supply of gas to meet the demands made by the engine. The general construction of a Koerting producer of the suction type is shown in Fig. 45. The plant

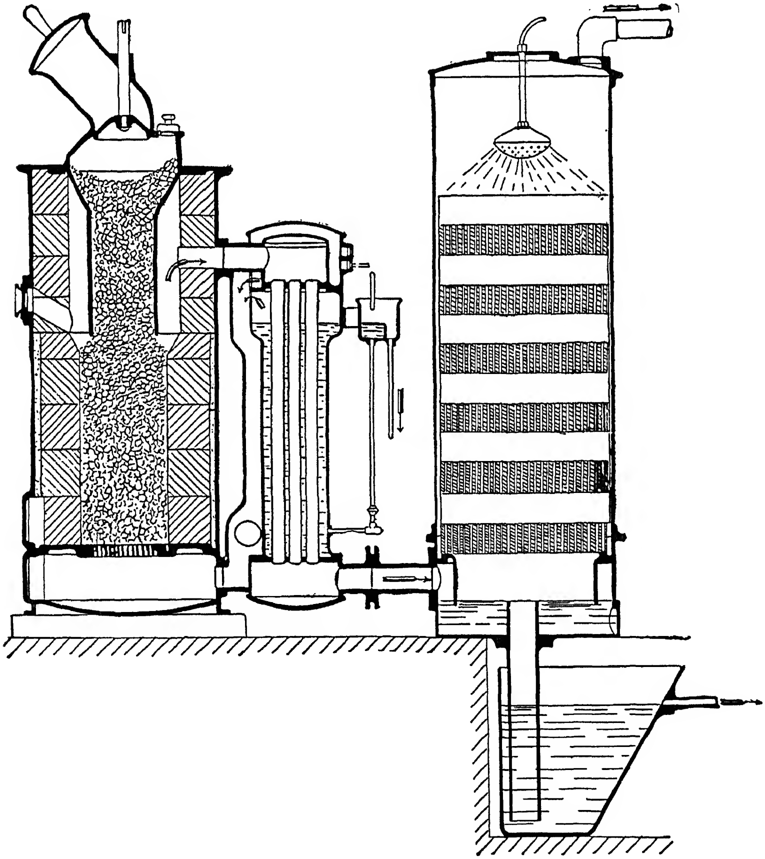


FIG. 46. SECTIONAL VIEW OF SUCTION PRODUCER.

consists essentially of a generator or producer, an evaporator, a scrubber or purifier, and a sawdust purifier.

Fig. 46 shows the sectional view of a generator and scrubber.

Generator. The generator is a vertical steel shell, cylindrical in

form and lined with fire-brick. It is fitted at the bottom with grates similar to those in a vertical boiler and at the top with a hopper having an air lock through which coal is fed to the fire.

Evaporator. At each charging stroke of the engine a quantity of air and gas is sucked out of the generator and passes through the evaporator. This device performs the double function of generating the steam and cooling the gases, and resembles in form a small tubular boiler. The gases, in passing down through the tubes of this boiler or evaporator give up part of their heat to the water surrounding the tubes and evaporate sufficient steam to supply the generator. The water supplied to the evaporator passes, wherever it can be conveniently arranged, first through the water jacket of the engine, where it takes up considerable heat. In passing to the generator a fixed amount of air is allowed to be drawn in and mingled with the steam, thus supplying the oxygen necessary for the partial combustion of sufficient coal to maintain necessary generator temperatures.

By this arrangement it is obvious that the heat necessarily abstracted from the hot gas on the way to the engine, as well as that taken from the heated cylinder walls, is returned to the generator in the water and air with which it is supplied.

Scrubber. The gases generated from ordinary fuels, especially from soft coal, are unfit, because of entrained impurities, to be used uncleansed within the cylinder of an engine. The amount and nature of these impurities naturally vary widely with the kind of fuel used, being nil for pure carbon.

The impurities to be removed from the gas generated from a ton of fuel are, for anthracite coal, from one to two pounds of ammonia, traces of sulphur and from five to ten pounds of tar, and from bituminous coal, from four to five pounds of ammonia, sulphur varying from "traces" to five per cent., and from ten to twelve gallons of tar.

In the case of suction producer plants using anthracite coal and carbonized fuels, such as charcoal and coke, the purifying process requires only a washer or scrubber. From the evaporator the cooled gas passes through a vent valve into the bottom of the scrubber and up through a bed of coke over which a spray of water is continuously running. While passing through this wet coke, the gas is

further cooled and cleansed of any fine ash or foreign matter which it may have carried over from the generator.

Sawdust Purifier. The gas leaving the scrubber descends through a vertical pipe and enters the sawdust purifier. Within the purifier it rises to the top through a short vertical pipe, and spreading over the entire cross-section of the cylindrical shell, filters down through two or more layers of sawdust supported on wooden gratings. The size of this cylinder allows the gas to travel very slowly and any impurities, such as tar, moisture and dust, not separated out in the scrubber are caught in the sawdust beds.

The comparatively large volume of the purifier also constitutes a suction receiver which reduces the pulsating effect due to the suction of the engine and makes the pull on the generator practically constant.

Starting. The plant is started by first building a fire on the grate of the generator and charging it with coke or coal, the chimney pipe being open and the engine gas pipe closed. Air is forced through the generator by means of a small hand blower until the charge is well ignited, the vent valve being turned so that the smoke will escape to the atmosphere through the chimney.

When a part of the gas is to be used for heating or other outside purposes, the blower or exhauster is placed in the gas main beyond the scrubber and so operated as to put the gas under sufficient pressure to force it through the pipes to the place of consumption. In this case the vent valve is placed behind the exhaust fan and arranged to divert the smoke into the chimney while starting up. The fuel having become incandescent up to the bottom of the hopper, the passage to the chimney is closed and the gas is tested by igniting a small jet from a test cock. If the gas burns with a reddish-blue flame not easily extinguished, the valve leading to the engine may be opened and the engine started. As soon as the engine has made a few revolutions it will pump its own gas, and unless the exhaust fan is required to force the gas through an outside system it can be stopped.

When the plant is to be shut down the generator is filled up with coal and the vent valve to the chimney opened to a mark which has been predetermined to admit the passage of just sufficient air to maintain a fire. Opening the vent valve to the chimney closes the communication with the scrubber and the gas which it contains can be used the next time the engine is started.

These producer plants consume only a very small amount of coal while the engine is shut down and are much more economical than boiler plants which, while the fires are banked and no power is being used, aften consume ten per cent. or more of the amount of coal required for the performance of their rated capacity. The plant after being shut down can be put in operation at full capacity in a few minutes and, on account of the heavy bed of burning coal carried at all times, meets the requirements of wide fluctuations in load with great promptness. In operating small plants it is necessary to charge coal through the hopper only about every two or three hours, shaking the fires to break up the bed of coal and remove ash, and inspection of the evaporator to see that it is properly supplied with water may be made more frequently. The removal of ashes from the water-sealed pit is performed two or three times per day.

Among the numerous advantages possessed by suction producers is their low first cost, extreme simplicity, and the fact that being operated under slight vacuum any leak will have the effect of drawing exterior air into the apparatus instead of allowing gas to escape to the outside, as may sometimes occur in the case of pressure producers not under the care of skilled attendants. The steam used in these producers, being drawn in by a slight vacuum produced by the engine itself, is never above atmospheric pressure and hence requires no boiler for holding steam under pressure to operate injectors as in the case of most pressure producer plants.

Pressure Producer. On account of its unusual adaptability to varying conditions and fuels and ability to meet varying requirements of load, and because gas is easily piped to a distance without loss by condensation, the pressure producer, Fig. 47, may be employed in plants of over 75 horse power.

The chemical reactions involved in generating gas are practically the same for both the suction and pressure producer, the essential difference between the two types being in their mode of operation. In the former case the gas is sucked from the generating apparatus by the action of the engine itself, and in the latter case steam and air are forced into the producer by a pressure blower using steam from a small auxiliary boiler. This blower not only supplies the power necessary to overcome the resistance encountered by the gas in passing through the generator and the cleaning apparatus on its

way to the gas holder, but also introduces the steam, which through decomposition affords a means of controlling generator temperatures and by reducing the quantity of air used greatly increases the heat value of the resulting gas.

In the suction producer, steam is evaporated in a small evaporator

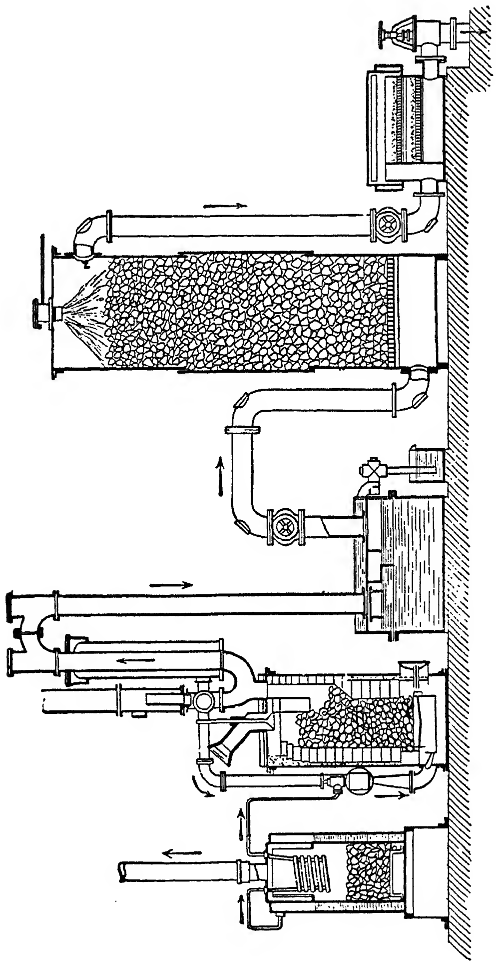


FIG. 47. PRESSURE PRODUCER.

at atmospheric pressure by the hot gases on their way to the scrubber; in the pressure type the steam is generated at from 70 to 100 pounds pressure in an auxiliary boiler. The evaporator of the suction producer is replaced in the pressure producer by an economizer which effects a heat interchange between the hot gases leaving

the generator and the air entering it. The economizer, like the evaporator, is similar in construction to a small tubular vertical boiler, and the gases pass through the tubes and the air around them.

While as yet anthracite coal is the only fuel that has proven entirely satisfactory in the suction producer, almost any fuel containing carbon and volatile hydrocarbons can be employed in the pressure producer, and any of these gases capable of forming a combustible mixture with air can be employed for generating power in a properly designed gas engine.

The gasification of bituminous fuels requires a producer of different construction from the one used for anthracite, as in approaching the incandescent part of the fuel bed tar is liberated, so that in an ordinary producer only gas high in tar contents can be generated. These tarry substances, however, can be decomposed at high temperature into hydrogen, carbon dioxide and carbon monoxide. If the tarry gases are passed again through incandescent coal the tar is destroyed and at the same time utilized by its decomposition. The simplest way to do this is to connect two or more producers, one behind the other, so that for instance the gas generated in the first producer, which is charged with green coal is passed through the second producer which contains hard fuel or fuel out of which the bituminous parts have already been removed.

An example of such a producer combination is the producer plant of Jahns, which is used in Germany for gasifying a low-grade residuum of the coal mines containing about 25 per cent. combustible matter.

For ordinary fuels and small plants, however, this system is rather complicated; therefore a different producer construction has been devised in Germany for gasifying lignite briquettes, in which the gas outlet is provided near the grate. This producer works by down-draft and is charged from the top. The tarry gases go through the incandescent fuel, whereby the tar is converted into gas.

More perfect producer plants for bituminous fuels combine practically two producers into one, *i. e.*, the producer has two "burning layers," one on top and one on the bottom, the gas being removed between the two. The process in its first stage is similar to the common retort gas process; the upper layer corresponds to the retort; here the tarry matters are driven out and the fuel coked. In the lower layer the tar is fixed and the coke gasified. The opera-

tion is regulated by the quantity of air admitted to each one of the two burning layers. The gas leaving these producers is fairly cool, so that it is unnecessary to use an evaporator, while with a producer for anthracite or coke an evaporator of sufficient size is essential.

In the Mond producer which is of ordinary construction soft coal is gasified for the purpose of recovering the by-products, especially the ammonia. On account of the high cost of these plants they are only used for very large units. As all the by-products are utilized, the gas produced is very cheap.

CHAPTER IV.

ELECTRIC POWER.

As a means of power supply for practically every purpose, the electric motor drive stands preëminent. It is without a rival in many fields of activity and is rapidly superseding older methods in all classes of service because of certain positive advantages not possessed by mechanical methods of power transmission.

Within the last few years the manufacture of electric motors has grown enormously and is to-day one of our largest industries devoted to an engineering product. This growth is due entirely to the merits of the motors themselves. Where power users have investigated the economic features of the electric motor drive, it has invariably been adopted. There are many instances where the nature of the work or the location will admit of no other form of power application, and in the majority of cases, even where the circumstances are most favorable to mechanical drives, the electric motor presents decided advantages.

The electric method of driving is particularly advantageous where low head room is encountered, since with individual drive there are no belts and in the group method the number is greatly reduced. Accordingly the obstruction to light is minimized or removed entirely, resulting in better conditions of illuminations, either by day or under artificial light, and in better ventilation as well.

In operation, the electric motor is efficient and consumes power only in proportion to the load it is called upon to carry. The frictional and electrical losses in the motor, when operating, are small and are entirely eliminated when the machine is stopped. It is ever ready to work and will do so greatly beyond its normal rated capacity which is based on operation for a reasonable time. It will deliver power for short periods largely in excess of its rated capacity without damage and at about the same efficiency as when normally loaded.

Many power distribution problems present difficulties, as, for instance, separate buildings not adjacently located, scattered location of the machines in building, the desirability of locating the mill

buildings or shops away from the source of power, so that the factories may be convenient to labor, railroad facilities, etc. These conditions are easily met by the use of the electric motor, which is an independent unit and may be located wherever found convenient —on the wall, ceiling or floor, or best of all, attached to and forming a part of the machine.

Overtime operation may be easily carried on with economy if electric motors are directly connected to the machines, as the power is only consumed when the machine is in operation. If the group method is employed, a careful disposition of motors and machines will eliminate much waste power as compared with mechanical systems of driving.

There are many individual cases where power is required in small quantity and intermittently, for ventilating fans, elevators, etc., where no other form of power could be used to such great advantage because of the inconvenience of getting the power producer in readiness to do the work and because of the attention required while in operation.

There are classes of service where the electric motor is being used because of its ease of movement and ease of relocation, as in mine work, where it is used for coal cutters, pumps, ventilating fans and haulage, the motors often being located thousands of feet from the power station. By no other system can work be accomplished so effectively, nor the power transmitted with such ease. Where conditions as such above noted arise, there is no competition.

In places where fire risk is ever present, and on account of which the buildings must be scattered over large areas, as in powder and dynamite works, chemical plants, etc., the electric drive is without a rival. Motors may be located wherever desired and power transmitted to them with but a fractional part of the losses occurring in other transmission systems. The enclosed or the induction motors present absolutely no fire risk. With mechanical drive, overheated bearings have often been the cause of disastrous fires. The elimination of belts overcomes this source of danger.

The adaptability of the electric drive to difficult or otherwise prohibitive power problems is now well established, and its field is daily expanding. Furthermore electric drive has been directly responsible for the creation of many industries whose power requirements could not be fulfilled by any other means.

An analysis of the elements entering into a mechanical power application will show that there must be a supply service, which is accomplished mechanically by a water wheel, a steam engine or gas engine, from which prime mover the power must be conveyed to the point of application by belting, ropes or shafts directly geared to the prime movers.

Belts or ropes are flexible factors, which slip, stretch and wear out. To render satisfactory service they must be given constant attention. They are links which are limited in their capacity, length and the direction they may take. When power must be distributed over some distance or area, it is necessary to relay, or to interpose shafting and belting from the first shaft to the second and so on, until the final destination is reached. In each and every one of the belt units there is slipping and surging under change of load, which results in an irregular speed and the inability to have positive power always at the shaft and driven machine. In many classes of industries an absolutely uniform speed is required for the most successful production, which is not possible with belt transmission. In other classes of production the machines require a means of adjusting the speed as the operation progresses, and this can only be done by interposing complicated mechanical speed-changing devices.

Contrasted with the foregoing conditions, there is in the electric drive an absolutely uniform rotative movement in the prime mover which is transmitted through the efficient service wires (easily installed to any required distance) direct to the motor, resulting in a maximum of effort on the shaft of the machine without shock or vibration.

Where speed changes are required in the producing machine, there can be installed an electric motor, which has characteristics enabling its speed to be adjusted to exactly the right condition required by the operation being carried out. This adjustment of speed is accomplished easily, economically, effectively and with positiveness, so that the operator can predetermine the conditions and then carry them out with exactness.

In many operations it is essential that control of the power application be had from a distance, and this condition can only be met by electric power service, where the motor may be controlled from any distance. The instruments under the eye of the operator indicate exactly what is being done by the motor.

The electric motor is regularly manufactured in sizes ranging from one twentieth horse power up to those used in steel mills, which have a capacity of several thousand horse power. They are made of many different speed characteristics, as well as mechanical form, so that motors are available for all varieties of service. For installations, where existing types are not entirely suitable, a motor may be made exactly to suit the conditions to be met, either mechanical or electrical. This is possible because the elements of motor designs are definite and well understood; therefore a motor may be designed whose exact performance under any conditions of operation can be foretold.

A crowning feature of the electric motor is that its reliability is the same whether large or small and the small unit nearly obtains the high efficiency of the large unit. Neither of these features is true of steam or other types of engines.

There are some requirements of service where it is not convenient to provide an operator; these conditions are easily met by the electric motor, since it may be automatically controlled, *i. e.,* started and stopped whenever required. Since motors have no wearing parts requiring frequent attention, only an occasional inspection is required.

Electric motors are made in a large variety of sizes, and as new fields are developed, new forms and types of motors are made to meet them. The speed and operating characteristics of the motors are suitable for all character of work, from slow-moving machinery to the rapidly revolving centrifugal pump.

Where electric motors are used, it is no longer necessary to consider the power plant as the controlling factor in an industrial works. The building may be located at the point most convenient to the labor market, or to the transportation facilities, and where light and healthful surroundings predominate.

The floor space required may be arranged with the single view of its suitability to the conditions of the manufacture, and the machines located so as to be in line with the manufacturing sequence.

If desirable the works may consist of a number of isolated buildings, each so located and equipped that it will be specially adapted to the problem of manufacturing only. The producing machinery does not require a predetermined location in reference to the power supply, and may therefore be placed so as to save labor and time

in handling the product, which of course creates additional capacity at a decreased operating cost.

There are in general use two methods of applying electric motors, *i. e.*, the grouping of certain machines belted to a short-line shaft, driven by a motor of just the right capacity, thus limiting the friction and waste power due to unnecessary shafts and belt transmission; or by directly connecting the motor to the driven machine and driving power. Each method is very extensively used and the selection is dictated by the conditions of the problem.

Where the group method is used the shafts are light, short, easily kept in alignment and have much less friction or waste power than with the usual mechanical drive; thus the maintenance is less than when long shafts are employed.

The proper grouping of machines on short shafts driven by small motors eliminates many belts necessary in mechanically-driven plants, and permits changes in the location of machines with but small expense.

The most economical, flexible and desirable method from every point of view consists in driving every machine by an individual motor directly connected to it and forming with it a complete unit. The advantages resulting from this method are many and will be found efficient to offset the first cost in a short period.

Accessibility to machines is an exceedingly important factor in saving labor. Where the workman is not hampered by belts and shafting his work is greatly facilitated. Some machines should be located with the length of the works and others crosswise; this arrangement can readily be accomplished with electric drive.

For group drive the electric motor may be mounted on the floor, wall or ceiling with equal success, thus saving space. As it has a uniform rotary movement, there are no shocks or vibrations to the building structure.

The service wires used for supplying electric power to the motors are relatively of small diameter and easily erected. No special or heavy supports are required. They may be changed and relocated if conditions should demand, and, moreover, it is not necessary that they shall be limited to any predetermined direction or location.

The rapidly changing conditions of competition demand that new methods of manufacture be constantly adopted, and that new machines be installed which often change the regular order of manu-

facture, making it necessary to rearrange a number of the machines. This condition is easily and quickly accomplished if the electric drive is used, since little work is required other than the relocation of the machines. As there are no line shafts or main belts, they do not require consideration as to their capability to supply power to the new arrangement.

Extensions of plants are continually being made, and where the electric drive by individual motors is used and the power taken from the central station, the problem is reduced to one of floor space and machine. The central station will provide the power whenever called upon.

On the other hand, during times of business depression, the proper distribution of electric motors enables the manufacturer to decrease his power costs proportionately to the work being done.

Where purchased power is available, it is not necessary that an entire establishment be changed from mechanical transmission to electrical at once. The plan of transformation can be made and then the most wasteful drives superseded at first. The convenience and increased economy are sure to result in a speedy transformation of the rest of the equipment. Many of the large electric power installations of to-day had their beginning in the use of a few motors.

In some cases of old-established plants, where the power equipment is well installed and answers the purpose fairly well, electric drive has been used as an auxiliary form of power with great satisfaction. The outlying loads are removed from the mechanical system and long lines of shafting are shortened so that the mechanical efficiency is improved.

It is an established fact that under the most favorable conditions of service, where the shafting, hangers and belts are kept in the best conditions, the friction load is from 30 per cent. to 35 per cent. In the great majority of factories the figures are higher and the average will be found to be from 40 to 60 per cent.

It is usual to consider the friction load of a plant as that condition when all belts are on loose pulleys, and consequently it only includes the load of the shafting, the bearing friction, the weight of the pulleys and the slipping friction of the belts.

When a system of shafting and belting is transmitting power, the strains due to belt tension increase the bearing friction and the

waste power is increased. Friction loads must be considered from several view points, *i. e.*, the horse power per lineal foot of line shaft and the horse power per square foot of floor space, before an approximation may be made of the real friction losses, account being taken from the load factor of the machines.

The plant load factor is the ratio expressed in per cent. of the actual power used to the total rated power of the motors connected. It shows that all the motors are not running at their rated capacity all the time. In some classes of work the plant load factors are high, as in a textile mill they will probably be 85 per cent. On the other hand, the plant load factor in a machine shop will be from 25 to 35 per cent., other industries falling between these extremes.

Considering the case of a mill where the power loads are relatively large per foot of shafting, it will be found that large belts are required and that these are apt to cause strains on the shaft, consequently a tendency to pull it out of alignment.

In factories where the machines are scattered much shafting is required to furnish power to the machines. In these cases the horse power per foot of shaft is low, and therefore the friction loads are high. It is always a difficult matter to keep long line shafts in sufficiently good alignment to prevent undue friction.

It is a well-known fact that where mechanical drives, even if well laid out, have been supplanted by the electric method of distribution, a substantial saving of power has been made. Savings have been even made in cases where the losses of the electrical system seem to be as great as the no-load friction losses in the mechanical drives, a result that indicates an increase in the friction of a system of shafting and belting when transmitting load.

A motor located on the machine to be driven has many advantages, not only direct but indirect, both classes of which result in economy, reduce labor and increase output. This means a decrease in the cost of the product per unit of output, and at the same time an increase in the revenue of the investment in costly machines and tools.

There are no losses in the service line or motor when the motor is stopped. When, however, the motor is running, but not called upon for power, the combined electrical losses in the motor and line are small compared with a system of shafting and belting in

operation and ready to supply power, but delivering none to the machine.

This decreased cost will vary with different installations and operating conditions, but will always prove to be greatly in the favor of the electrical system.

The ratio of the time a machine is in operation to the possible working time is termed the time factor. A low machine time factor is an item of great expense, yet it will be found that many machines will have time factors as low as 20 per cent. (in some cases even less), ranging to approximately 85 per cent. as a maximum of those machines of the automatic type or in continuous operation, as in textile mills, cement mills, or similar service.

A motor directly connected to the machine may be started and stopped with the machine, thus saving a large amount of waste power required to drive idle shafting used to serve the machine. The load on the machine is rarely at a maximum, varying in some cases from 40 per cent. to 80 per cent., depending upon the class of work, and as the shafting and belting must be of a capacity to take care of the maximum load, the friction load is considerable, often as much or more than the load of the machines.

With the direct-connected motor there are no losses when the machine is idle, and when in operation the motor requires power only in proportion to the actual work being done. The efficiency of the electric motor is nearly the same between half-load and any overload within its capacity. It is obvious that this nearly constant efficiency is a direct gain in favor of the electric system of driving.

Motors directly connected to machines increase their productive capacity, varying with the kind of machine and the class of material being worked, but whatever class there is always an increase.

In some mills every effort is made to keep the speed constant, so in mechanical transmission the engineer must be careful to keep his engine within one half to one revolution of normal speed. Other classes of operations, as in paper making, etc., are dependent upon uniform speed. Where motors have been directly connected to machines, they apply uniform speed of the same number of revolutions all the time, resulting in an increase in the production of the machines. There is no slipping with the electric motor and there is no surging in speed as in belted systems.

By the individual drives the space required for machines is con-

siderably reduced, or stated another way, more machines can be located in the same space, thus reducing the floor rental charge.

This condition is due to the better arrangement on the one hand and to the fact that provision does not have to be made for belt angles, etc. Machines may be located in the center of the aisles, which cannot be done with belt drive.

The arrangement can be changed with ease to suit any new conditions arising, due to changing conditions of manufacture or markets.

The saving in space is a large item and should be given careful consideration.

In nearly every factory some condition arises whereby it is desirable and necessary to work some portion overtime. Work will get out of balance, a rush must be put on some specialty or a repair job must be done; in fact, overtime is almost inevitable. It is always very expensive, and doubly so, when required in a mechanically driven plant. The shafting and belting must all be kept in motion, thus involving the entire friction load of the plant, which may be many times that of the actual work being done. With individual motor drive the cost of power is only that of the machines being actually operated, and therefore is that of a fraction involved in any mechanical system. The saving in power under these conditions will pay a good percentage of the non-productive charges.

With the individual motor drive there are no belts, and consequently no obstruction to light. The dirt which rapidly-moving belts always keep agitated is absent, and the ceiling and walls may be kept clean, thus better reflecting the light. It is a well-established fact that better work can be done by daylight than at night; so also can the best work and the greatest quantity be done in a well-lighted, well-ventilated and clean factory. The conditions are contagious, the men are cleaner by example. Surroundings and environment always directly affect workmen, and therefore they should be the best.

These advantages may be said to be indirect ones and of doubtful direct value, but as a cheerful man in a well-lighted and clean shop can accomplish more at the same time, it is certainly economy to provide the necessary conditions to bring this about. Individual drive does it in the best manner possible. Motor drive is better than the usual mechanical system.

Since the number of belts and shafts is lessened in group drive and entirely eliminated in the individual method, the danger risk to the workman, the fire risk due to hot bearings, and the distribution of oil over walls, ceilings and floors, due to rapidly-moving belts, are eliminated.

The care required by the electric drive, either in the group system or in the individual method, is less than with mechanical drive.

The electric service wires do not require any attention whatever, and the motors require only an occasional inspection, cleaning and oiling. The bearings and commutators of direct-current motors are the only wearing parts. The bearings are self-oiling and commutators last for years.

There is no wear in the induction motors except the bearings, and this is reduced to a minimum.

The efficiency of the electric drive versus that of any other form, whether it be gear, rope or belt transmission, depends upon the condition of the problem. The efficiency will vary with the size, type and character of the works, whether they are composed of a single building or a group of buildings; with the nature of the load factor or the power service; with the load factor and the machine used for manufacturing and the character of the product. Almost invariably will the electric motor drive show direct economies, by which is meant a decrease in the cost of power.

In making comparisons of efficiency of one form of drive against another, the indirect advantages must be given consideration in their proper places. As the electric drive increases production in certain industrial lines, improves the quality of the product in the others, decreases the time involved for certain other operations, which means a greater quantity of product in the same equipment, these indirect advantages should be capitalized and credited to the first cost. In determining relative efficiencies, the broad problem should be considered, taking into account all advantages inherent in the system, and in determining the efficiency the cost of the product per unit output should be the final measure of the efficiency of any other form of drive. This will undoubtedly show in favor of the electric drive in various amounts, depending entirely upon the nature of industry to which it is applied.

The use of electric motor drive for distribution of power results in the absence of or the elimination of many conditions heretofore

absolutely required when a system of belts and shafting is used for the transmission of power from a central source. In a factory involving but a single building there would naturally be but one engine plant from which the power is transmitted by means of belting and shafting to the various floors. This arrangement usually requires a belt tower or raceway, either head shafts from which the floor belts are taken or extraordinarily heavy main line shafting. Frequently right angle drives are required for changing the direction of the line shafting, and in some cases vertical shafts with their attendant difficulties have been used.

All these expensive, in some cases wasteful, elements in the transmission problems are eliminated by the use of and the proper distribution of the electric motor. Whatever shafting may be used in the electric motor drive is comparatively light and is short in length, consequently easy to maintain in alignment, therefore less wasteful of power due to friction. Many lighter belts and all of the heavy ones are dispensed with entirely, and the heavy supports required where large line shafts are involved are eliminated, thus contributing to a lighter building construction by the use of the motor drive. The dirt, dust, noise and vibration always attending belt and shafting transmissions is largely reduced or dispensed with entirely.

The comparison in cost between the installation of a mechanical system of belting and shafting transmission and electric power by means of properly selected motor units varies with the class of the service. As above outlined, there may be reduced cost of building construction, and where the horse power per lineal foot of line shafting or per square foot of floor space is relatively small, the electric installation will compare favorably with that of the mechanical plant. The saving by the use of any improved device should be capitalized and balanced against the first cost of installation, and if this is done, there will never be any question but that the use of the electric motor drive will pay a handsome profit on the investment.

CHAPTER V.

TRANSPORTATION OF SOLIDS.

Conveying of Materials. Certain physical characteristics of materials, while by no means making it impracticable or undesirable to handle them by elevators and conveyors, necessitate unusual care in the selection of the proper design and manufacture of such machines, if they are to prove reliable and durable.

These characteristics are: sharp cutting edges or joints of coarsely broken substances of hard texture; abrasive dust; stickiness or adhesiveness; moisture; corrosiveness; and these are particularly apt to exist with the materials handled in chemical and metallurgical establishments.

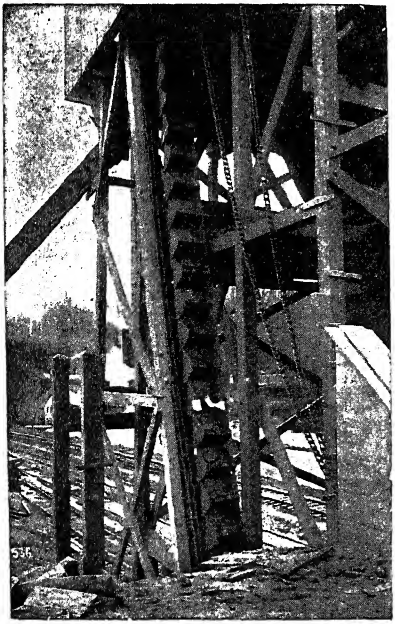


FIG. 48. BUCKET ELEVATOR.

For this reason the simpler types of scraper conveyors are not very generally used, it being found better to use some of the types of conveyors which carry the material. An exception to the foregoing class is the screw conveyor, which does push its material, although the weight of the conveyor itself is supported independently of the trough. Even with this it is generally necessary to use special types of screw conveyors designed particularly to meet the more difficult conditions.

Cuts are shown of cast-iron conveyors with cast-iron trough and renewable bearings of chilled iron, the flights of the conveyor and the trough being of unusual thickness to resist wear, and both flights and bearings being easily renewed.

For the purpose of clearly defining the most representative classes of machines, selections have been made from different types as designed and made by the Link-Belt Company.[1]

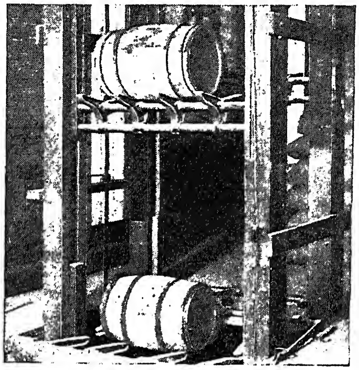


FIG. 49. VERTICAL CARRIER OF THE CRADLE TYPE.

Fig. 48 shows a continuous bucket type of elevator for frangible material. The face of each bucket, after passing over the head

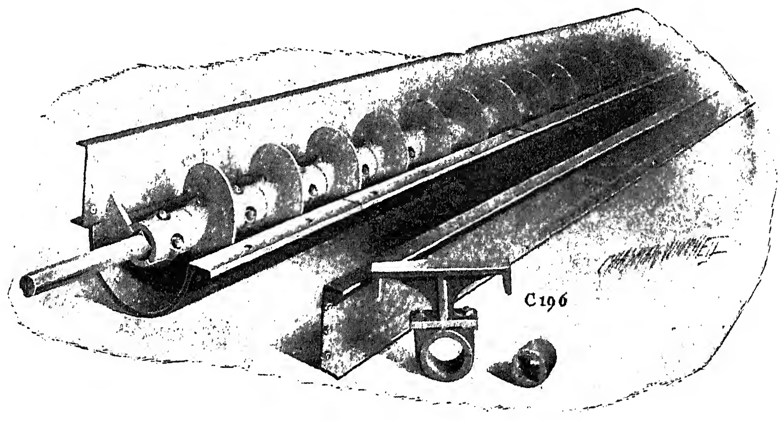


FIG. 50. SCREW CONVEYOR.

wheel, serves as a chute to direct the flow of the contents from the next bucket.

Fig. 49 is a view of a vertical carrier of the cradle type in which loading and unloading are automatically accomplished by means of

[1] Philadelphia, Chicago, Indianapolis.

projecting arms or fingers meshing with those of the carrier tray. These loading and unloading devices may be fixed or movable, and the carrying motions up and down may be simultaneous or alternate.

Fig. 50 shows a screw conveyor with sides made of channel iron. Other types have sides and cover of heavy, rolled steel plate.

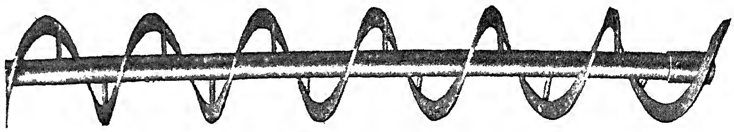


FIG. 51. STEEL RIBBON SCREW CONVEYOR.

There is also shown a steel ribbon conveyor (Fig. 51) usually made of large diameter so that it may revolve at moderate speeds and have comparatively large wearing surface of flight. This conveyor is especially adapted to handle materials that would adhere and ball up, forming an obstruction at the hangers.

Fig. 52 shows a water-jacketed ribbon screw conveyor as used

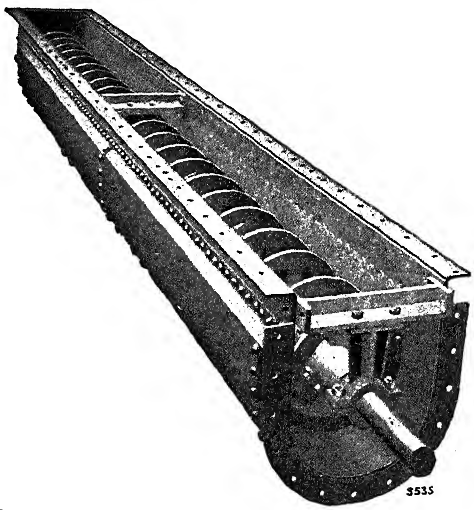


FIG. 52. WATER JACKETED RIBBON SCREW CONVEYOR.

in sugar refineries for taking the sugar from the vacuum pans to the crystallizers, the water-jacketing cooling the mixture sufficiently to assist crystallization.

Belonging to the class of screw or spiral conveyors is the paddle conveyor, one of the forms being shown in the illustration of a sugar mingler (Fig. 53).

Fig. 54 gives a comprehensive view of a plant employing different types of screw conveyors, with which the work proceeds as follows: the raw cane-juice, pumped from the purifying tanks into

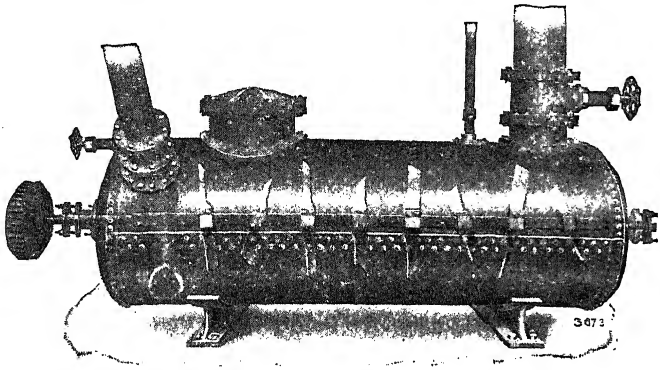


FIG. 53. SUGAR MINGLER.

the vacuum pans, is drawn off from these to water-jacketed screw conveyor and delivered to the crystallizers. From the crystallizers the plain ribbon screw transfers to minglers, which in turn supply the centrifugals. The latter discharge to the slat conveyor by which the crystals are carried to the bucket elevators for delivery to the bins.

Fig. 55: rotary conveyor having internal spiral plates or vanes. Largely used for conveying, cooling or drying soda, metallic ores, etc.

The carrying-conveyors are of three general types: apron conveyors, bucket conveyors and belt conveyors. Apron conveyors are usually made of steel, though illustrations are shown of machines of wood construction. There is also the corrugated steel apron with either shallow or deep corrugations.

Fig. 56 shows an apron conveyor, built of heavy overlapping steel plates and secured to two strands of special chain supported by self-lubricating rollers. This type of machine is extensively used as a picking-table and as a carrier for billets and other metallic substances, either hot or cold.

Fig. 57: A platform carrier made up of wooden slats attached at each end to alternate links of "Ewart" link-belt. The illustration is from a photographic reproduction of a machine installed for a large electric storage-battery company to transfer the hot zinc plates from the moulds to the saws. Other applications of this type of

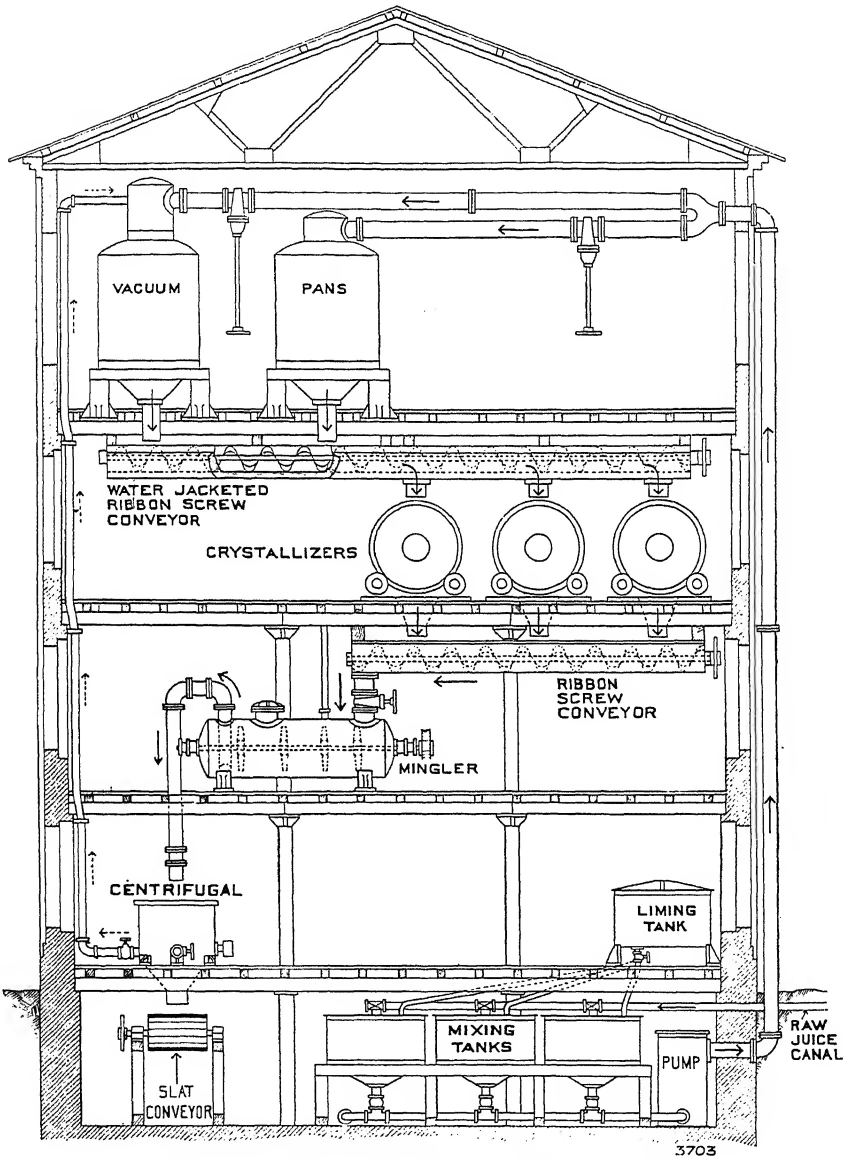


FIG. 54. SCREW CONVEYORS IN A SUGAR REFINERY.

carrier have been made where the work involves movement of goods in a wet or moist state, the construction permitting drainage or drip during the transfer. Modifications have been designed for use in handling packages, boxes, cans, etc., some of the forms having raised

bars, or cleats, at intervals, which push the load resting against them. The type used for conveying casks and barrels, see Fig. 58, has the front and back ends of the slats chamfered, which serves the same purpose as the raised cleats employed in the machines for lighter

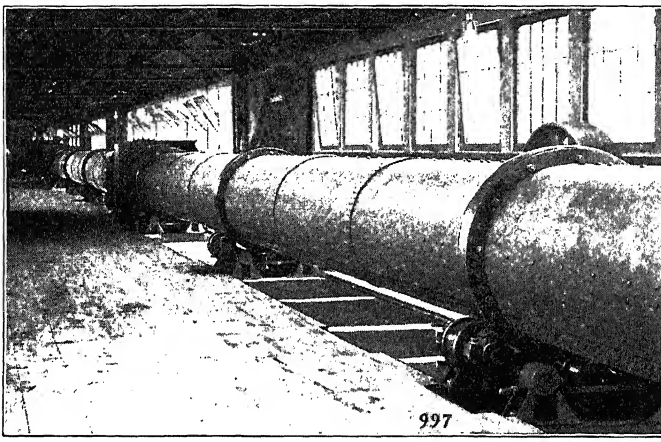


FIG. 55. ROTARY CONVEYOR.

service. This type of carrier is of great utility where vessel loading and unloading takes place: the in-board end is pivoted so that the ports of the vessel may be accommodated at various tides. Men

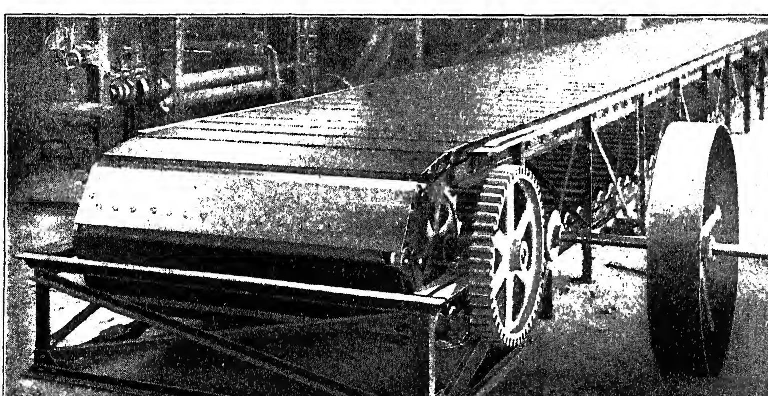


FIG. 56. APRON CONVEYOR.

push loaded trucks onto the moving platform which makes the transfer to warehouse or pier.

Another form of carrier, in which the travel proceeds in one sur-

face plane, see Fig. 59, has the head and foot wheels set horizontally. Loading and unloading takes place from the outer sides. The construction of the machine illustrated, which is in use at the foundry of a prominent electrical manufactory, differs somewhat from the

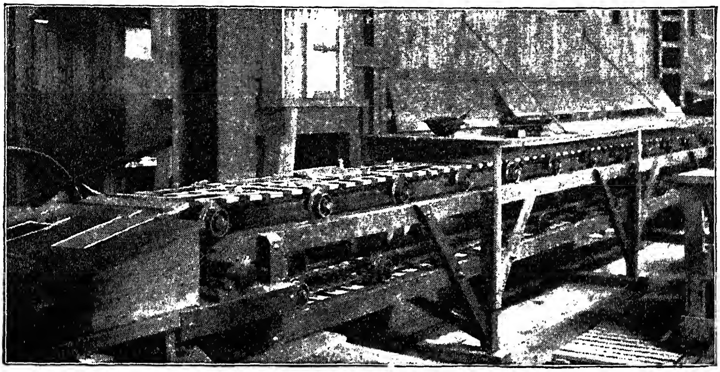


FIG. 57. PLATFORM CARRIER.

usual arrangement: the plates are attached on the under side to "Dodge" cable chain (Fig. 70) and supported on the inner end by small, grooved wheels. The outer end is supported by a larger wheel mounted on a swivel truck and running, as does the other, on a

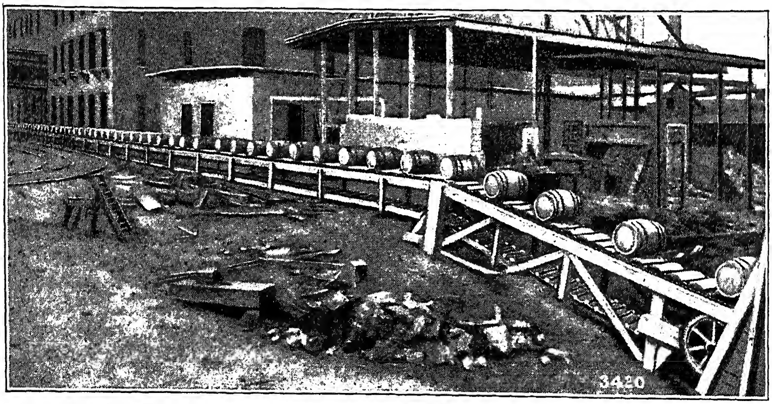


FIG. 58. CARRIER FOR CASKS AND BARRELS.

T-iron track. The inner corners of the plates are cut off diagonally to permit free turns around the terminal wheels.

With the aprons as shown by Fig. 60, the beaded edges, which form the corrugations, have a considerable overlap which does not

open in passing around the sprocket wheels, thus serving to carry material, even when quite fine, without permitting it to fall through, and approximating very closely the functions of a true continuous

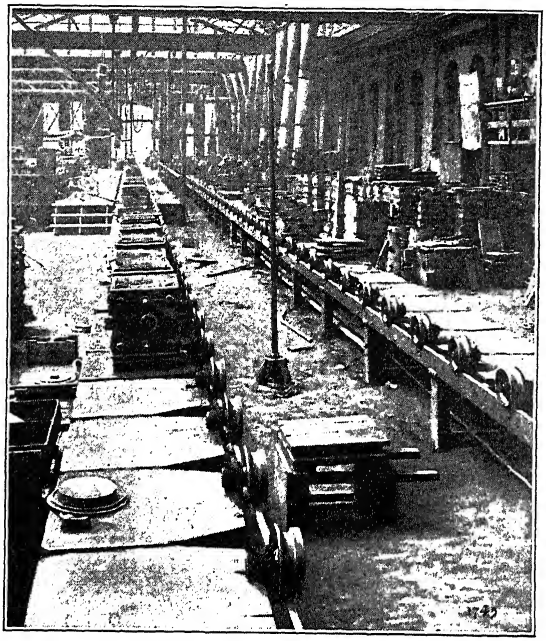


FIG. 59. CARRIER TRAVELLING IN ONE SURFACE PLANE.

belt. The corrugations also assist to greatly stiffen the apron, making it suitable to handle coarsely broken materials, the individual lumps of which may be of very considerable weight. Corrugations also

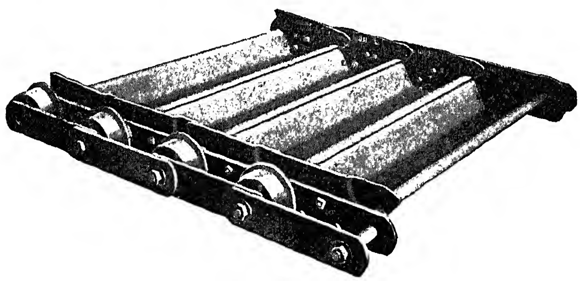


FIG. 60. APRONS.

enable conveyors of this type to operate at inclinations up to 35 degrees without the material sliding backward.

Fig. 61 shows a view of a bituminous coal-conveying outfit at a

coke plant. Cars discharge run-of-mine through a steel hopper set between the rails to a crusher (Fig. 140) from which it is delivered to an overlapping pan conveyor for transfer to a continuous bucket elevator which discharges to bins or pocket.

In the heavier installations, and particularly where materials of

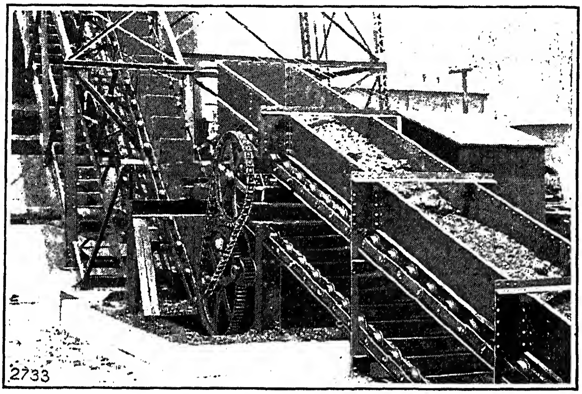


FIG. 61. BITUMINOUS COAL CONVEYING OUTFIT.

a gritty nature are handled, the chains should be fitted with case-hardened steel bushings, on which the rollers turn, and the rollers should be from two to six or eight inches in diameter and made self-

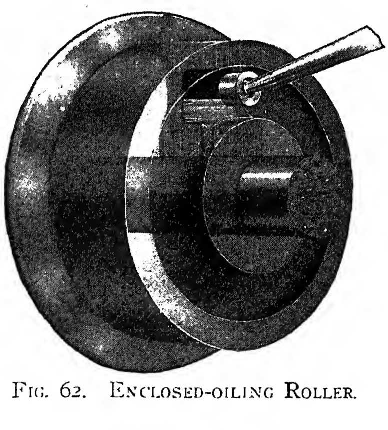


FIG. 62. ENCLOSED-OILING ROLLER.

lubricating. For the simpler and lighter installations, plain rolls of small size, turning on the chain pins, may be used.

Fig. 62 shows the enclosed-oiling roller, as devised for sure and ready means of lubrication. The oil chamber, grooved and packed

with an absorbent ring, is charged through oilers fitted with a spring cap. Pressure from the outside causes this cap to yield; when pressure is removed, the cap springs back into position, and effectually prevents the oil from escaping and foreign matter from entering.

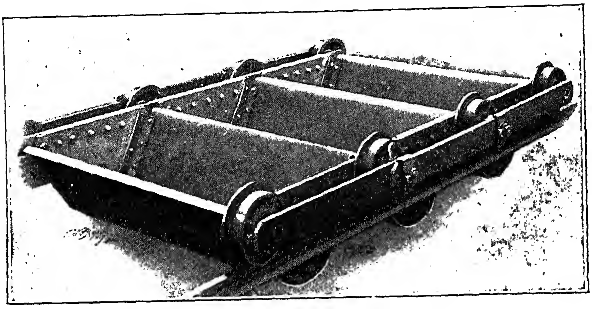


FIG. 63. OPEN TOP CARRIER.

The ultimate development of the deeply corrugated apron conveyor becomes the open top carrier (Fig. 63) consisting of overlapping steel buckets or pans rigidly attached between roller chains. These buckets are usually of very large sizes and capacities, indi-

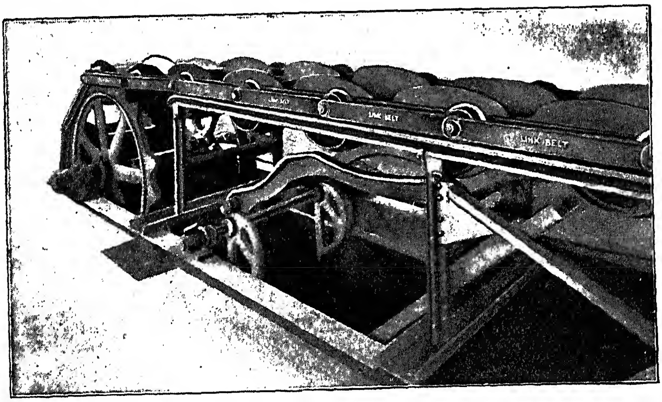


FIG. 63A. PIVOTED OVERLAPPING-BUCKET CARRIER.

vidual installations showing dimensions of $5' \times 2'$ and handling 1,000 tons per hour.

By suspending the pans or buckets with trunnions between the chains so that they always swing freely and in a horizontal position under the action of gravity, a carrier is obtained of very wide application and utility, designed to lift as well as convey and to follow

any desired path. The most common adaptation receives the coal along the lower run, elevates it and discharges it wherever desired

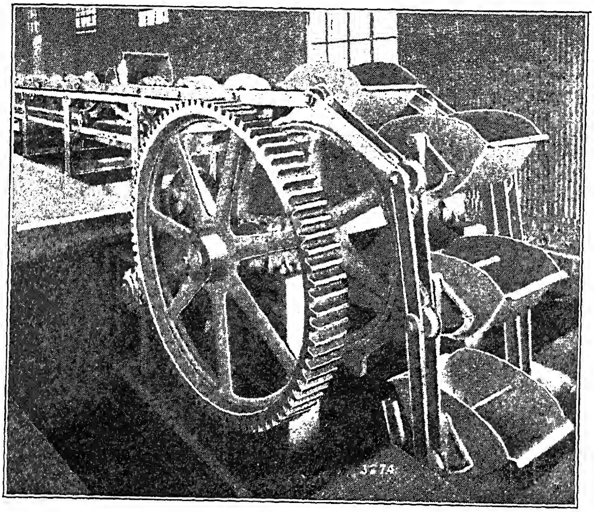


FIG. 64. PIVOTED OVERLAPPING-BUCKET CARRIER.

along the upper run by inverting the buckets with suitable mechanism. Carriers of this type may be made without overlapping lips on the buckets, but these lips are most desirable, because they pre-

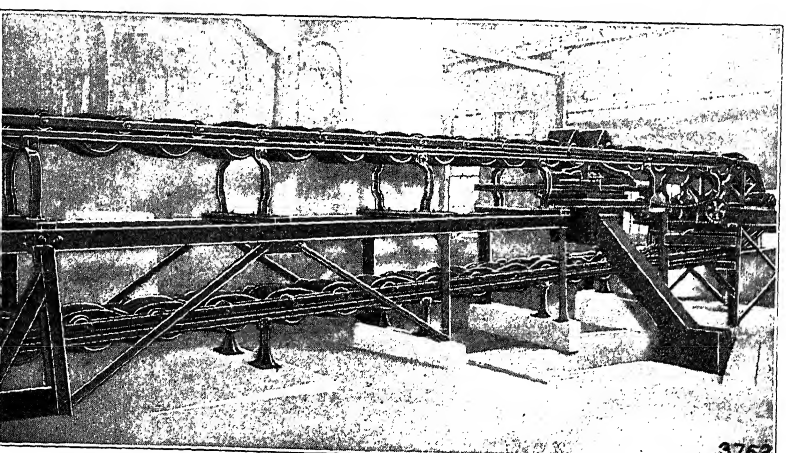


FIG. 65. UPPER AND LOWER HORIZONTAL RUNS OF CARRIER.

vent material from falling between the buckets in loading. Where the buckets overlap, however, their natural movement in passing

around the four sides of a rectangle brings the overlapping lips into such a position that they interlock and prevent the buckets passing from the lower horizontal to the ascending run without interference and spilling of the material handled. To obviate this, the most approved form of this type of carrier has the buckets suspended from projections of the inner chain links beyond the points of articulation, see Fig. 64. By this means the buckets travel through a longer path in passing around the wheels than do the chains from which they are suspended, and thus automatically unlap themselves.

Fig. 65 shows the horizontal runs of the carrier installed at an extensive cement works. Hot clinker is handled at the rate of forty tons per hour.

Belt Conveyors. Belt conveyors are largely used and of much service in many places. They consist of a continuous belt, sup-

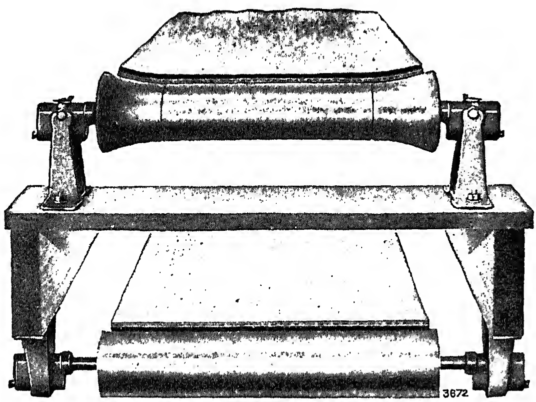


FIG. 66. PRESSED STEEL ROLL FOR BELT CONVEYOR.

ported for very light service by a trough, but almost universally by rollers placed at intervals of from two and one half to five feet on the carrying run, and at intervals twice as great on the idle run. The supporting rolls may be plain cylinders such as are used for the return run always; but more commonly to increase the conveying capacity without the material spilling over the edges of the belt, the rolls are made of such a form that will trough the belt along its carrying run. The drawback to the use of belt conveyors is the expense of frequent renewals of the belts, the life of which, under favorable conditions, hardly reaches, on an average, three years. Belts fail from the continuous strain set up between the plies by the troughing action, and for this reason experience proves that it is

the best practice and the greatest economy to trough the belt as little as possible.

The best forms of supporting-rolls are shown in the illustrations: Fig. 66 shows the pressed steel roll with bell-shaped ends. This provides sufficient trough to resist a tendency of the material to spread out sideways and spill off the belt, and the troughing, while still so slight, nevertheless, gives the belt a carrying capacity very much in excess of that attained in the perfectly flat type. Where very large capacity is required the four-roll support (Fig. 67) is

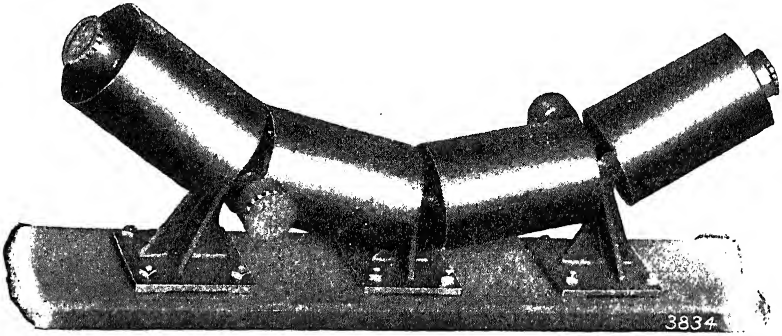


FIG. 67. 4-ROLL SUPPORT FOR BELT CONVEYOR.

best, as it gives a relatively deep trough without the sharp bends, incident to a three-roll support; localized bending of the belt is always to be avoided, and the belt allowed to assume as nearly as possible a uniform curve. To insure this the belts of greatest durability are of uniform structure throughout, with or without an extra cushion of rubber on the carrying surface, to protect the fabric of the belt. Where belts have more plies of fabric at certain parts of their structure than others, the bending is localized, and the failing tension in the belt sets up internal strains which ultimately separate the plies and destroy the belt.

As conveyors which carry their load, and particularly those which elevate as well, are definitely limited in capacity by what the belts or buckets can hold without spilling, some means of regulating the supply is essential to well-designed machines of this class. For the smaller sizes of material a rotary feeder resembling a paddle wheel, and with three or four compartments, is used. For the more coarsely broken materials the supply is regulated by a small corrugated apron feeder (Fig. 60) or by a reciprocating plate (Fig. 68). Both of

these devices work beneath the hopper, having an opening of sufficient size to admit the largest pieces without choking—the size of the opening, as will be readily appreciated from the diagrams, being quite irrespective of the quantity of material it is desired to feed. The feeders must extend beyond the natural angle of flow of the

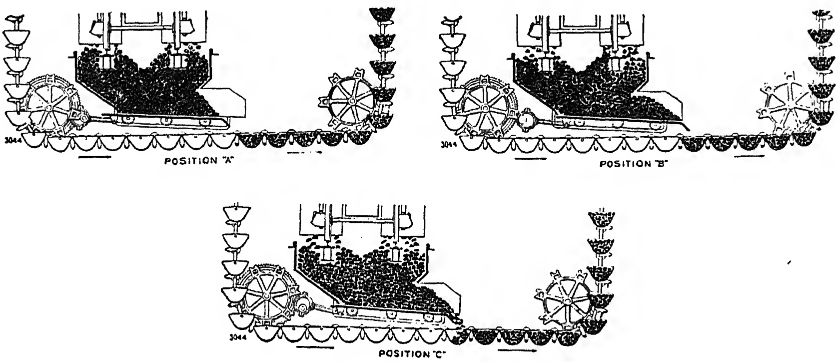


FIG. 68. RECIPROCATING FEEDER.

material through the opening, the material thus having no further movement, except as imparted to it by the forward travel of the feeding conveyor or by the reciprocating motion of the plate.

The corrugated apron type is employed when the distance between the receiving point and the carrier is too long to make the use of the reciprocating feeder practicable. The apron feeder materially reduces the power required to operate the crusher by giving it a uniform load. The successive operations of the reciprocating type are shown: the forward movement begins with position *A*, reaches its limit at position *B*, and at *C*, the plate being pulled back, the material which has just been carried forward, drops into the buckets.

Conveying and Power-transmitting Chains. The first great improvement by which chains were given a broad working field such as is now occupied, was in the invention of the "Ewart" malleable iron detachable link-belt, an illustration of which is given in Fig. 69.

This form of chain, which was first applied to agricultural machinery, is still in use in all departments of the conveyor industry, principally in the lighter service. Equivalent chains with closed ends and pin connections are also used.

Great convenience is a characteristic of the detachable chain.

With it there is no necessity for the tinkering which always accompanied the use of the early forms of riveted strap links. It is made in different sizes, and there is always a link to fit a link; thus, availability still gives a distinctive value to the chain which is of world-

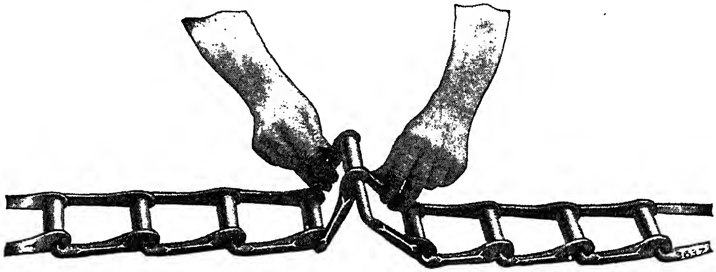


FIG. 69. "EWART" LINK-BELT.

wide usage. Present-day practice leads to the use of fewer types of chains, each being adapted to a special line of work.

The "Dodge" cable chain, shown by Fig. 70, followed the intro-

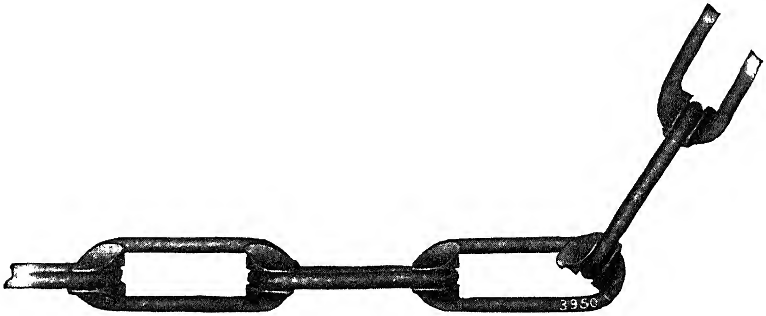


FIG. 70. "DODGE" CABLE CHAIN.

duction of the "Ewart" and was devised for heavier duty. The removable blocks with which the links are fitted, offer large bearing surfaces to both links and wheel teeth, and permit the chain to adapt

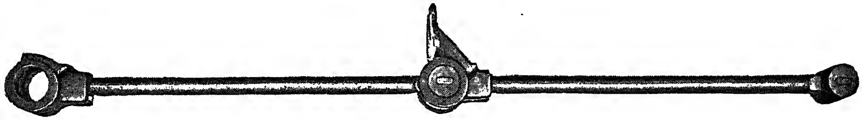


FIG. 71. "MONOBAR" CHAIN.

itself to any turn in a vertical or horizontal plane. While given over to a wide range of work, the largest application has been in the anthracite coal fields and to the "Dodge System" of coal storage.

FIG. 72. "LEY" BUSHED CHAIN.

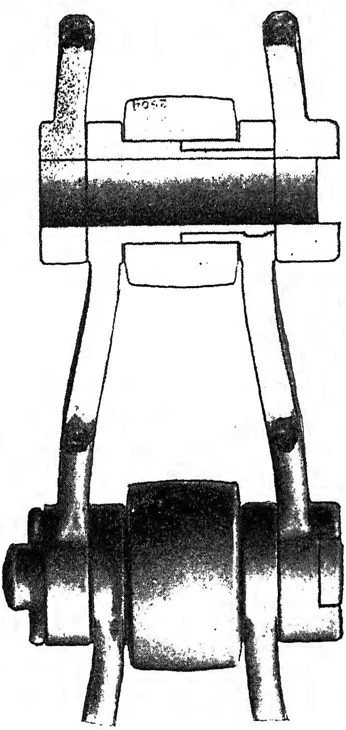


FIG. 73. ROLLER CHAIN.

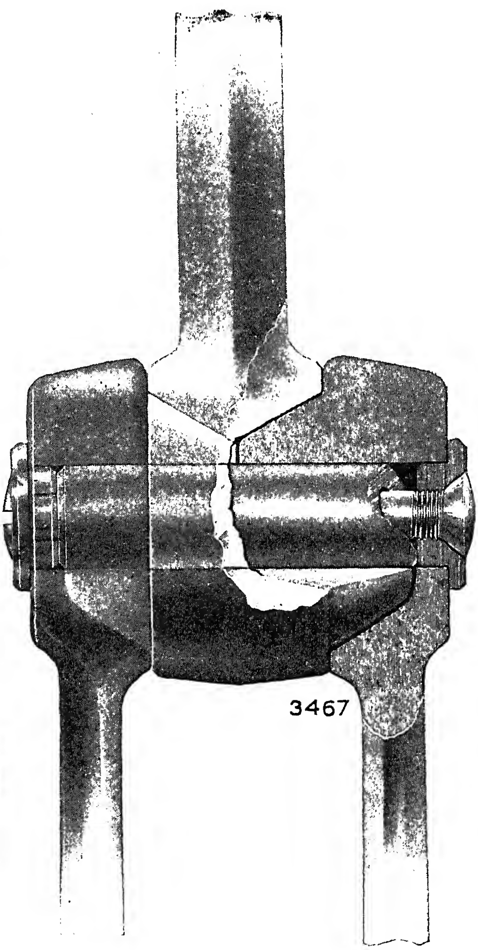
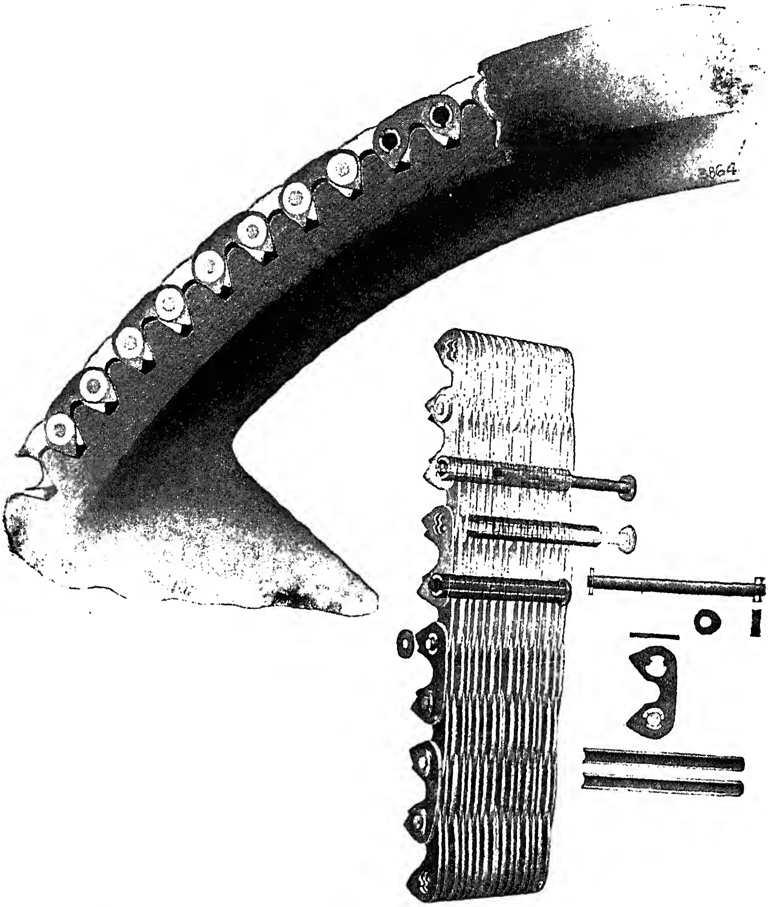


FIG. 74. "MAXIMUM" CHAIN.

Fig. 71 shows a detail view of the "Monobar." This chain consists of a series of round bolts flexibly connected by malleable iron knuckles and sockets. Employed for conveyors of great length and large capacity, its use is approached in extent only by the two types



FIGS. 75, 76. DETAILS OF "RENOLD" SILENT CHAIN

mentioned in the preceding paragraphs. The features which give it superiority are: high tensile strength, it has no welds; lightness, resulting from few joints because of the comparative length of the bolts; durability follows because the bearing surfaces are large and

accessible to lubrication, and the bolts are entirely free from wear—while their roundness prevents clinging or lodging of material;

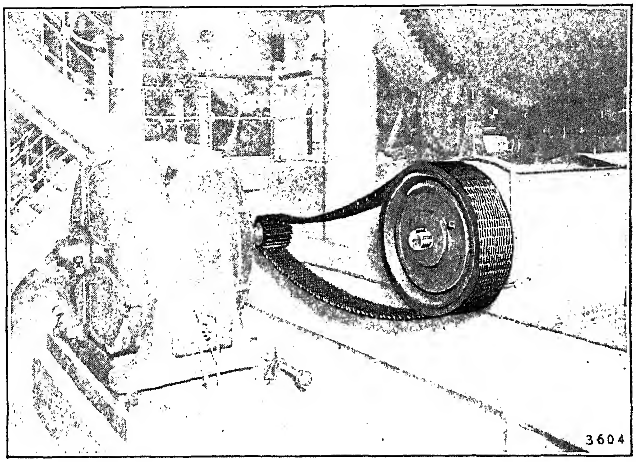


FIG. 77. SILENT CHAIN DRIVE FROM ELECTRIC MOTOR.

economy in maintenance results from the permanency of the bolts—which limits cost of renewals to a few joints or couplings.

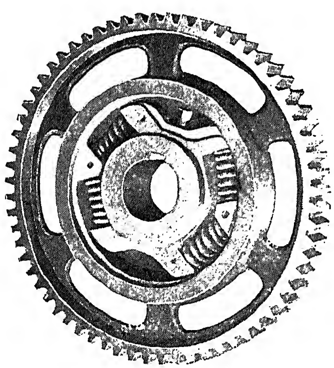


FIG. 78. CONSTRUCTION OF SILENT WHEEL.

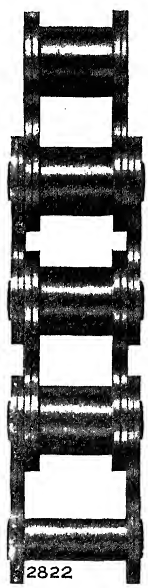


FIG. 79. ROLLER TYPE OF DRIVE CHAIN.

Fig. 72 illustrates a successful chain of the pin-connected type, the "Ley Bushed Chain," exclusively controlled by the Link-Belt Co., and used in handling gritty materials, such as ashes, coke, slag, cement, sand, etc. Articulation takes place between the pin and

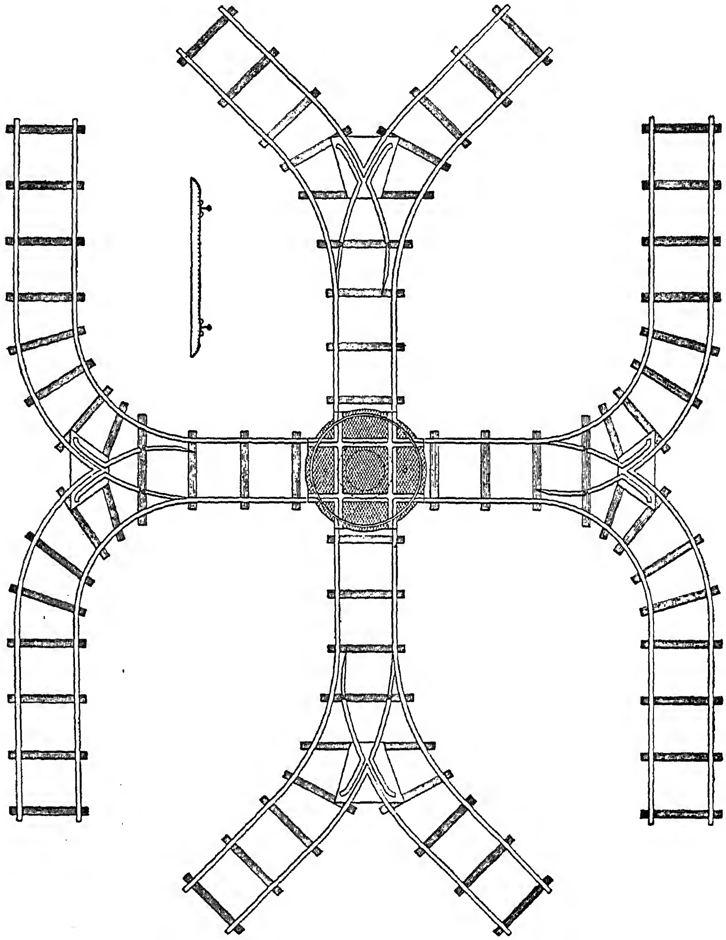


FIG. 80. TRACK SYSTEM.

bushing, both of which are case-hardened and renewable. The outside of the bushing is protected by a sleeve which obviates contact with sprocket teeth, and by making this a *rolling* contact, minimizes wear on the links and teeth.

Fig. 73 illustrates a chain of the roller type such as is used for double strand conveying. The construction, as will be seen from

the etching, is extremely simple and rugged: the two sides of the link telescope into each other and are held permanently in position so that the link is practically one piece. This makes a chain, the parts of which do not scatter when the pin is withdrawn.

"Maximum" chain: The most recent form of chain devised for extremely heavy duty is shown by Fig. 74. This is a high-grade

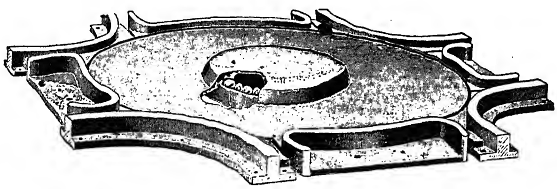


FIG. 81. TYPE "A" BALL-BEARING TURN-TABLE.

steel chain made up of single and double links, having great width of bearing surface and connected by bush-protected steel pins. Internal and external wear, while greatly minimized, is distributed over the complete bearing area. Combined with the over all width of bearing, and structural ruggedness, the general design indicates a chain of extreme power and great durability. The joint connection is formed of a hollow pin or bushing, which serves as the bearing pivot for the chain links, and effectively protects the solid

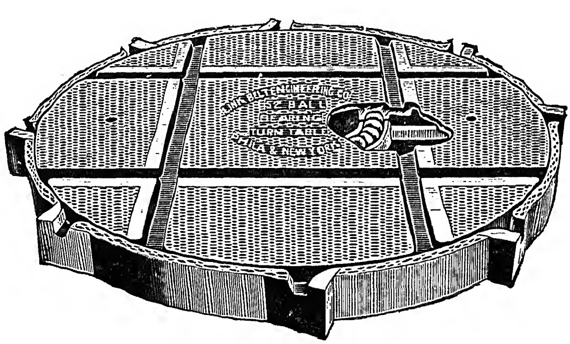


FIG. 82. TYPE "B" BALL-BEARING TURN-TABLE.

pin which it surrounds, leaving the latter to merely hold the ends of the chain together. These ends are so fashioned as to give a bearing-surface the whole length of the joint, and thus prevent destructive shearing and bending strains upon the pivot pin. As this pin turns freely in the bearing, which is packed with lubricant,

there results an evenness and a minimum of wear that govern to a great degree the lasting quality of the chain.

Driving chains, so called from their particular adaptability to

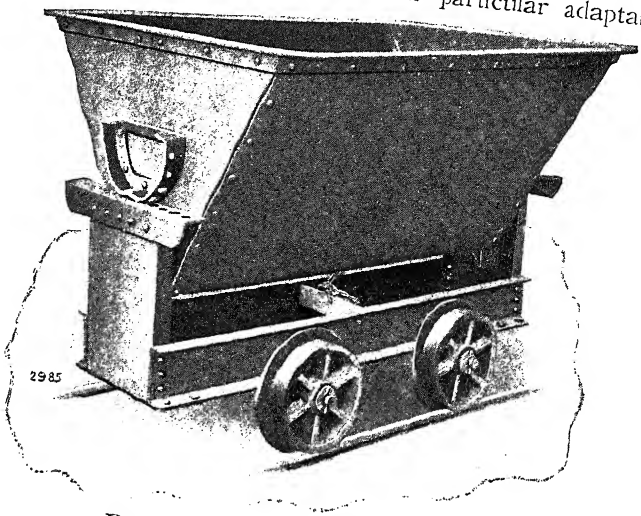


FIG. 83. SIDE DUMP TILTING CAR.

power transmission, reach their highest development in the Renold silent and roller chains. Fig. 75 shows a detail of the former type

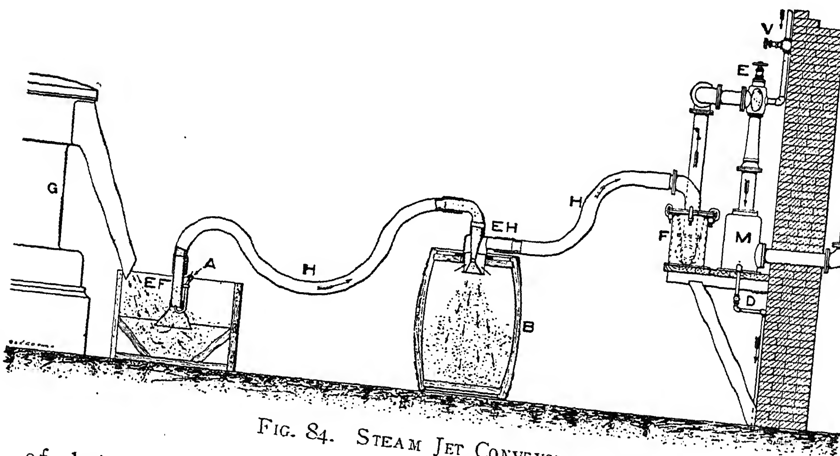


FIG. 84. STEAM JET CONVEYOR.

of chain and its wheel. The principal characteristic of the design is that the chain compensates for any possible wear by assuming a

larger pitch diameter, at the same time maintaining perfect contact with the teeth. A detail view of the construction is shown by Fig. 76; the joint is made up of full-width, case-hardened steel bushings and hardened steel pin. This improvement, besides allowing for the proper articulation, permits complete rotation of the pin and provides against uneven wear, though the accuracy of fit minimizes any

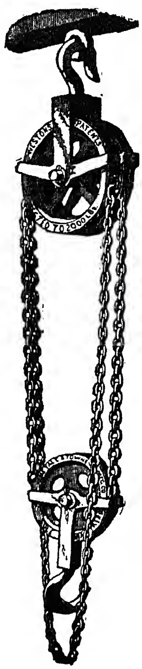


Fig. 85. Differential Block.

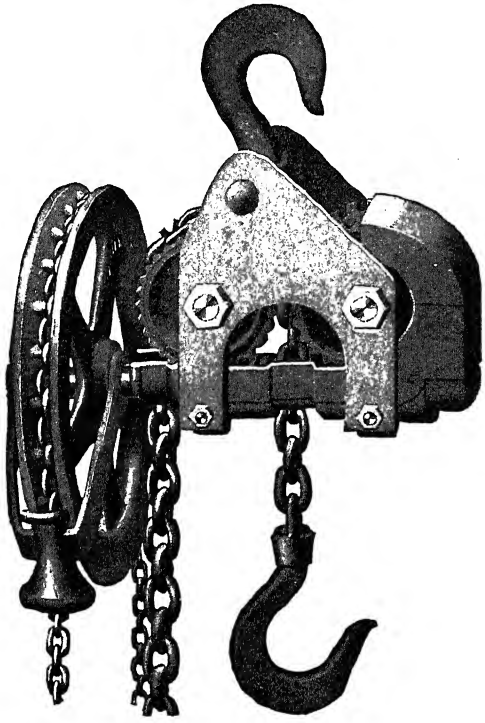


Fig. 86. Patent Hoist.

tendency to elongation or wobble. Another favorable point brought out is the absence of contact between the links and the pins, which relieves the latter of concentrated pressure and eliminates internal wear on links. The facility of the chain is indicated because it can be run at high or low speeds; will transmit any amount of power; can be used on long or short centers; gives a positive velocity ratio; can be used in hot, damp or cold locations; does not slip; prevents excessive journal friction; runs quietly. As a substitute for leather belting and spur gearing, it has given great satisfaction, superseding

both of these to such an extent that its introduction became an epoch-making circumstance.

Fig. 77 shows a drive from an electric motor, the larger wheel being constructed as shown by Fig. 78. The spring center which surrounds the hub was devised to correct variations in angular velocity, and to absorb pulsations or jerk, thus protecting the chain from shock

The roller type of chain, shown by Fig. 79, fills the gap between the malleable and the silent chain. With the former it is not advisable to exceed a speed of 500 feet a minute, while the latter may attain a speed of 1,600 feet a minute, though its economic range is

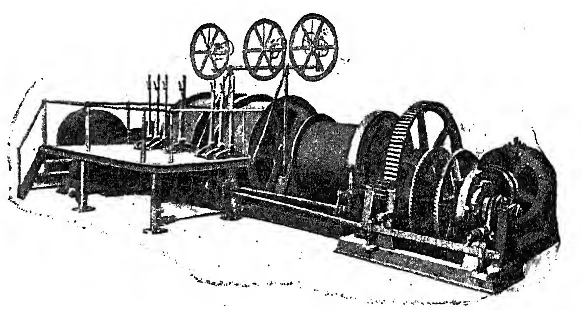


FIG. 87. HOIST.

between that and 900 feet. In the construction of the roller chain great care has been taken to provide joints of ample area to secure low unit pressures while having the roller, bushing, and pin hardened to the right extent to give durability without incurring disaster from brittleness. The most extensive use of this chain in America has been on drives of motor vehicles.

Complete information regarding both of the foregoing chains can be had only from the Link-Belt Company, sole owner of the American rights to manufacture and sale.

Industrial Railways and Cars. Industrial railway systems are of demonstrated convenience. Views are shown of a track system (Fig. 80) with ball-bearing turn-table, two types of the latter being illustrated by Figs. 81 and 82.

Fig. 83 shows a side-dump tilting car designed to handle ashes.

Other Transporting Devices. Fig. 84 shows an installation of a Koerting steam jet conveyor, which, by reason of the vacuum created, is used to advantage in handling dusty and poisonous chemicals. *A*

is the air admission, *B* a barrel, *D* discharge of condensed water, *E* exhauster, *EF* the suction foot, *EH* the discharge head, *F* the filter, *G* a pulverizer, *H* the suction hose, *K* discharge from exhauster, *M* muffler, and *V* steam valve.

Fig. 85 illustrates a differential block, Fig. 86 the box patent hoist. The principal feature of the latter is the use of a right-hand

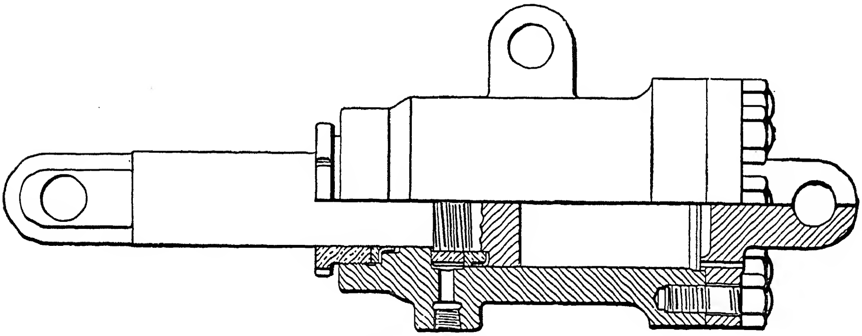


FIG. 88. JACK.

and left-hand screw on one shaft, working on two separate wheels, instead of two separate right-hand screws working or driving the rim of one lift wheel.

A hoisting installation is shown in Fig. 87.

Finally we have to mention the hydraulic jacks. Fig. 88 shows a type made by the Schutte and Koerting Co., Philadelphia.

CHAPTER VI.

TRANSPORTATION OF LIQUIDS.

For the transportation of liquids a large number of appliances, such as injectors, syphons, eductors, air jet lifts, montejus, pumps, etc., are on the market. According to the nature of the liquid handled these apparatuses are made of iron, copper, lead, bronze, hard rubber, or stoneware. Enamel is frequently used as coating.

Wherever possible acid-proof cast iron should be used. Pig iron showing the following analysis, and mixed in the proportions stated below, is exceedingly durable regarding the action of acids:

	A. Dark gray.	B. Light gray.	C. Mixed.
Silicon	3.5	1.5	0.7
Manganese	0.5	0.4	0.2 to 0.3
Phosphorus	0.2	0.2	0.2
Total carbon	3.8	3.5	3.5

All three qualities should be free from sulphur. To get the best result, A, B and C should be mixed in the proportion 2 : 1 : 1.

Injectors. The Koerting universal double tube injector, which is shown in Fig. 89, is extensively used especially for transporting water to the boiler.

B is the discharge; N the lower water nozzle; N_1 the upper water nozzle; O the overflow valve; P the lower steam nozzle; P_1 the upper steam nozzle; S the steam supply; W the suction.

This injector is a combination of two jets. The lower jet is proportioned for extreme temperature and for quick and strong action, which includes maximum high suction. The discharge is into the uppet jet where the water receives the additional strong impulse to carry it into the boiler. The pressure and volume from the lower jet corresponds to the steam pressure, and this is as it should be to answer the requirements of the upper or forcing jet. The varying volume insures the proper working at high steam pressure as well as at low, and increased pressure admits of increased high temperature.

The self-governing or automatic features are the reason why this injector gives the same high duty and works with the same strong

and positive action on the varying pressures of steam with highest temperature of feed water under pressure or high lift.

Universal Syphons or Steam Jet Pumps. These apparatuses are used for moving water or other liquids, where durability, low cost,

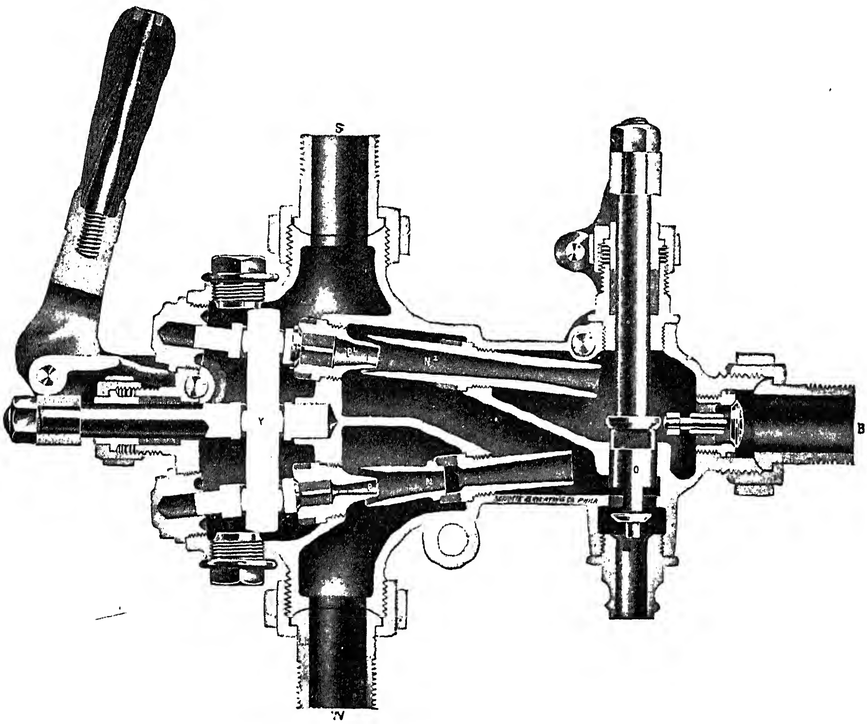


FIG. 89. DOUBLE TUBE INJECTOR.

simplicity of manipulation is of importance or where an increase of temperature is beneficial. They are made of brass or iron bodies, with brass nozzles.

These syphons are advantageously used for lifting bleaching liquor, milk of lime, water pulp, sugar juice, molasses, chemicals, etc. The extreme simplicity of the apparatus and certainty of operation at all times carry their own recommendation. In the majority of applications, where a heating of the liquid is necessary, the elevating of the liquid may be considered an almost costless operation.

Stoppages in suction pipes, strainer or in the apparatus are promptly cleared by providing a shut-off in the discharge pipe, which when closed will cause the steam to blow back and clear the obstruction.

Fig. 90 shows an application of these syphons for transferring

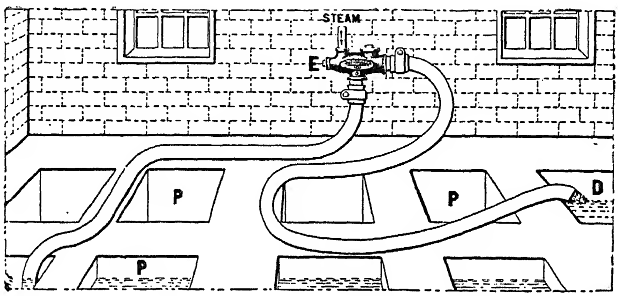


FIG. 90. SYPHON FOR TRANSFERRING LIQUIDS.

liquids from pits, in tanneries or chemical works. *D* is the discharge, *E* the syphon, and *P* the pits.

The most extended application of syphons is found in such chemical industries where, in addition to elevating and moving, a heating of the liquids is required. They are also used to advantage in place of centrifugal pumps for circulating lyes and extracts, and a slightly changed construction is successfully applied for artesian wells.

For the lifting of acids and other substances that have a corroding effect upon brass and iron, the syphons are made of lead, stoneware or porcelain.

Fig. 91 shows the arrangement of a lead syphon. *C* is the check valve, *D* the drain, *F* the strainer, *O* the delivery pipe, *P* the suction pipe, *R* the stop valve, *S* the syphon, *T* the tank, *V* the stop valve.

No lead burning is required in making connection to the syphon as the lead pipe is flanged true and smooth and is fitted to the syphon by means of suitable counter flanges. The flanges must be bolted perfectly tight and firm that no leaks occur. It is generally to be recommended to fix the syphon a foot or two above the liquid, so that the liquid has to be drawn up, and the syphon empties itself when not in operation. The steam pipe connection should be blown out with high pressure steam before connection is made to the

syphon. When there are lumps or floating particles in the supply, a strainer should be attached to the suction pipe. The syphon works best under certain conditions at a certain steam pressure, which has to be found out by throttling the steam. Therefore when such a syphon is installed it should be arranged as shown in the cut.

Valve *V* is throttled to the most favorable steam pressure and

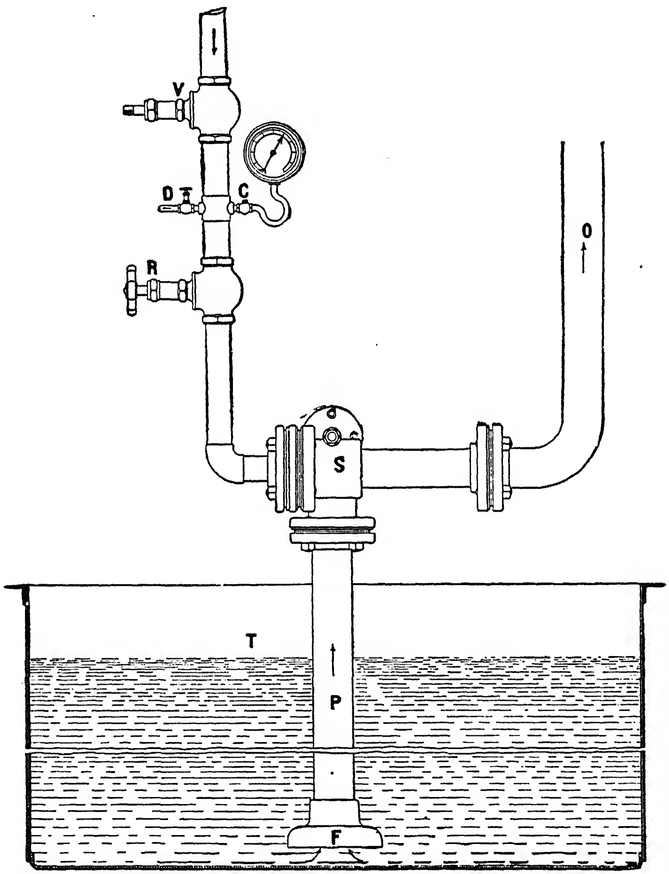


FIG. 91. LEAD SYPHON ARRANGEMENT.

locked in that position. Valve *R* is used for operating the syphon only. Before starting the syphon, valve *D* should be opened in order to draw off condensation. Care has to be taken that no traps occur in the delivery pipe and that the suction pipe is perfectly air-tight.

Air Jet Lifts. Air jet lifts are simple and efficient means for lifting liquids by means of compressed air, especially in places where piston pumps or steam jets cannot be used. The working of the air jet lifts is as follows: Air is pressed into the lower end of a submerged pipe. The air mixes with the water inside the air jet lift, forming a mixture of air and water, the specific gravity of which is lighter than water; thereby the column consisting of air and water is driven upwards. In other words, the apparatus works through the difference of specific weight of the two columns.

The arrangement, as shown in Fig. 92, consists of the discharge

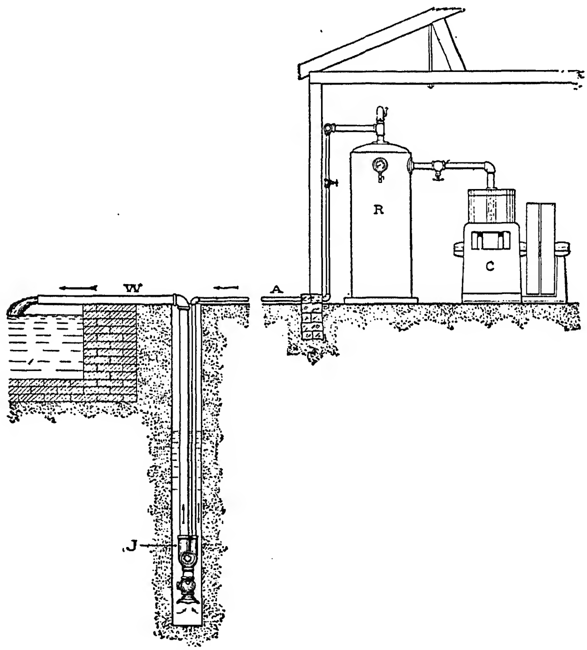


FIG. 92. AIR JET LIFT.

pipe *W*, the air pressure pipe *A*, and the apparatus proper *J*. The discharge pipe may be any kind of pipe which discharges the water freely, so that the water can get rid of the air.

The apparatus is so constructed that the air is distributed as uniformly as possible over the area of the water discharge pipe. In cases where the machine is put in a well there is usually provided a strainer on the inlet of the apparatus. In cases where the water is carried to the machine by means of a pipe, the connection of the

apparatus is made by means of an elbow. The discharge pipe and the air pipe are placed as close together as possible, so that the apparatus can be installed in narrow wells.

The apparatus is to be installed as deep under the level of the liquid as corresponds with the height of lift. To operate the apparatus it is only necessary to open the valve in the air pressure line, and the regulation of the quantity of liquid is done by increasing or decreasing the quantity of compressed air.

Besides the application of lifting water from wells by means of compressed air, these jets are used extensively in the chemical industry for handling acids, alkalies, etc., necessitating the use of such materials as lead, porcelain, stoneware, rubber, etc., which cannot be used to advantage in pumps with movable parts. The air jet lift provides the means to overcome this difficulty, as it can be made of any material. The advantage which this apparatus has, compared with lifts used in the chemical industries, such as acid eggs or montejus, is especially that it works continuously as long as compressed air and liquid are carried to the apparatus. Further one is enabled to exactly regulate the quantity required for a given time by regulating the quantity of compressed air. Further advantages are that it occupies little space and can be easily erected in sulphuric acid plants at the foot of the tower in ordinary sewer pipes, which are sunk in the ground according to the height of discharge. The apparatus throws the acid directly in the interior of the Glover and Gay-Lussac towers by letting the discharge pipes extend through the top of the towers. By arranging a plate inside, against which the acid is forced, the ordinary distributors on top of the tower are eliminated in a satisfactory manner. The acid air lift uses less compressed air than the acid egg and can be made of suitable material. For lifting sulphuric acid it is made of lead; for lifting concentrated acid, of cast iron; for nitric acid, of stoneware.

Automatic Montejus. This apparatus, in which also compressed air is used for lifting a liquid, is extensively applied in acid works, especially in the form shown in Fig. 93. In this type the liquid has to run to the machine by gravity, entering at *A* through a check valve. We assume that the tank is empty and that the full weight of the lower float *B* keeps the exhaust valve open, so that the liquid can freely run into the tank. The liquid rapidly covers the lower float *B*, but the buoyancy thus started is not sufficient to open

the air valve. This is accomplished when the liquid reaches the upper float *C*. The combined buoyancy of both floats shuts the air exhaust valve and opens the compressed air inlet, the liquid being now discharged through the check valve and the discharge pipe. The level of the liquid drops now rapidly under the float *C*, but the weight thus exerted is not large enough to shut the compressed air inlet valve. This is accomplished after the liquid has dropped below float *B*, the weight of the floats being now sufficient to shut the air inlet valve, and to open the air relief valve. The conditions are now again the same as when starting and the same operation is repeated. These acid eggs are made in the following styles: entirely of cast iron; lead lined, and entirely of copper.

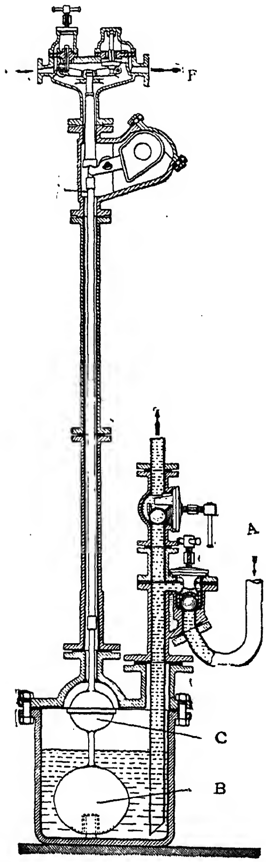


FIG. 93. AUTOMATIC MONTEJUS.

Water Jet Eductors. This apparatus, which, as also the injectors and syphons shown, is built by the Schutte and Koerting Co., Phila., is used to lift liquids by means of water having a high pressure, for instance, for draining cellars, or washing the filter sand in water works, to sink shafts in mining regions where high pressure water is at disposal and in places where, on account of insufficient space, a pump cannot be installed. The actuating water can either be taken from a local source, such as water works, natural water sources, etc., or can be supplied by pressure pumps.

The motive power of these pumps is pressure water passing through the apparatus with great velocity. This creates a vacuum and sucks in the water to be lifted, which is then carried along with the pressure water to the discharge outlet. Fig. 94 illustrates one of these eductors. *A* is the eductor, *Z* is the height of lift.

These pumps have the following advantages: They have no valves and no moving parts; they are not subject to wear and tear; they cannot get out of order; they are noiseless in operation; they

are the simplest and the most convenient apparatus, when high pressure water is at disposal.

Pumps. Another class of appliances for transporting liquids is the one operated by mechanically-driven machines, called pumps, in which the liquids are lifted by suction and then transported by pressure.

The pumps can be driven by steam, compressed air, electricity,

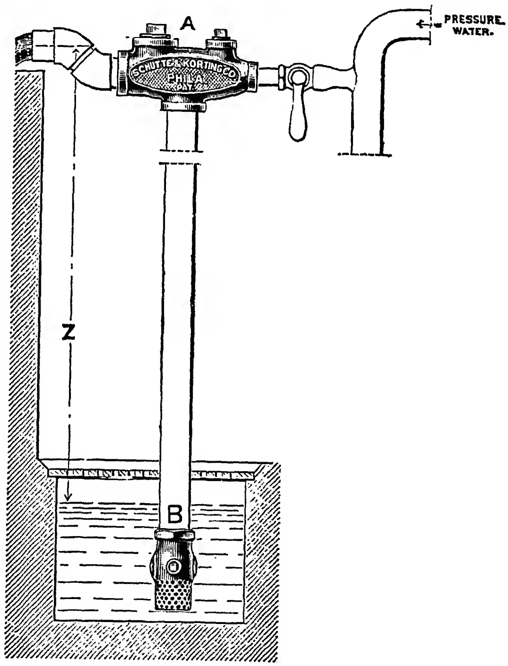


FIG. 94. WATER JET EDUCTOR.

gas power, hand, etc. Steam pumps are extensively used, as they can be located at any place desired. Fig. 95 shows the well-known Worthington type, Fig. 96 a Goulds vertical triplex single-acting power pump. These two types are so well known that a detailed description in this place seems to be unnecessary.

A type of pump which is now coming more and more into use, as the absence of valves in them is of great advantage for conveying heavy liquids and liquids containing sand, etc., is the centrifugal pump. This type is built in two constructions, the volute and the turbine. In the former the water is discharged into a volute or

spiral-shaped discharge chamber which terminates in the discharge pipe. In the latter type, diffusion or guide vanes are arranged in stationary passages around the circumference of the impeller to

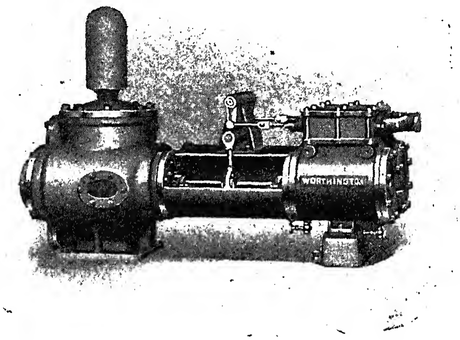


FIG. 95. STEAM PUMP.

direct the flow of water and reduce its velocity as it leaves the impeller without waste of energy. The turbine pump is peculiarly well suited for high pressures, as two or more impellers may be mounted on one shaft and enclosed in one case, the water being delivered from the diffusion vanes of one stage to the impeller of the next stage; the discharge pressure or head being the sum of the heads produced by all the impellers.. As there is practically no limit to this compounding, the turbine pump may be built for any desired pressure; and with proper designs and construction in multi-stage pumps, the end thrust may be practically overcome. Limit of capacity is fixed only by the limit of pipe sizes and sizes of passages in the pump; hence centrifugal pumps may be built to handle quantities of water far in excess of those commonly handled by direct-acting pumps. The centrifugal pump is equally well suited for handling small quantities of water.

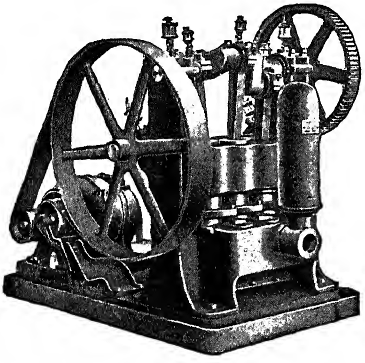


FIG. 96. VERTICAL TRIPLEX SINGLE ACTING PUMP.

Referring to Fig. 97, which shows a Worthington turbine pump, it will be seen that the path of the water from the suction opening

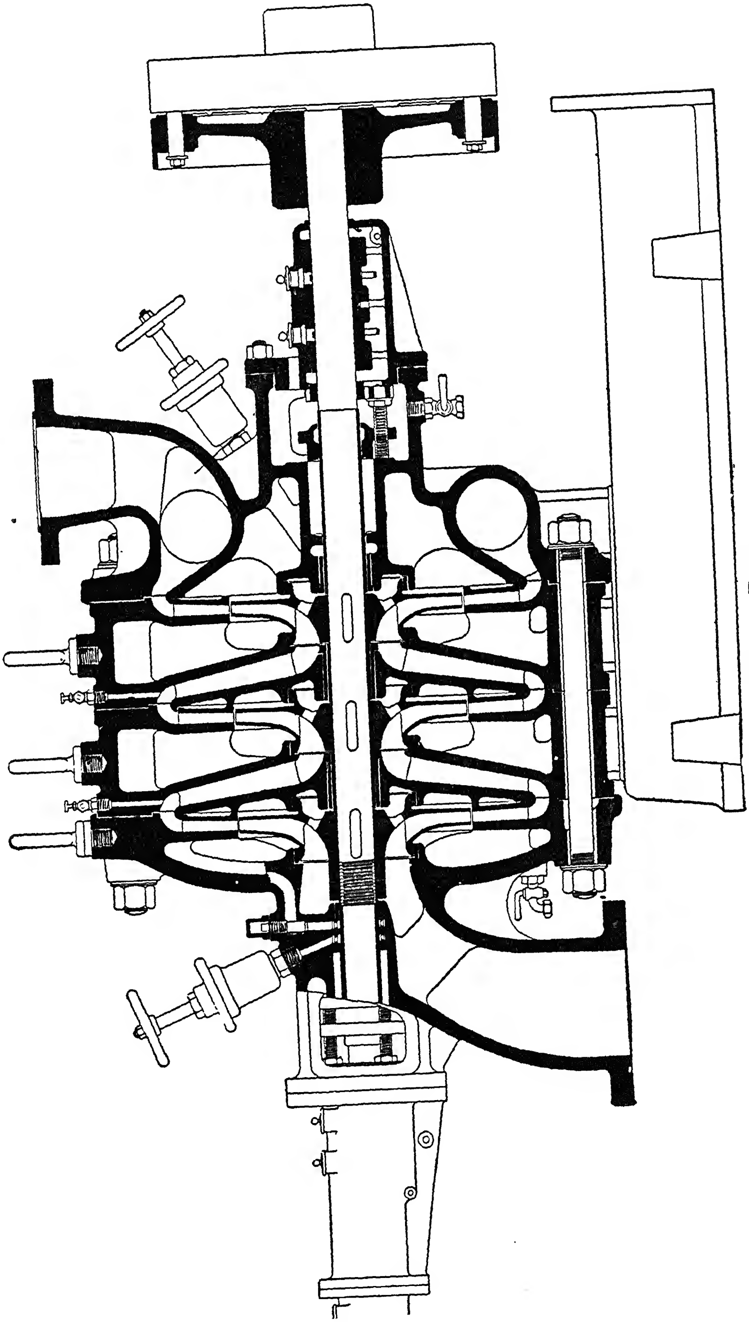
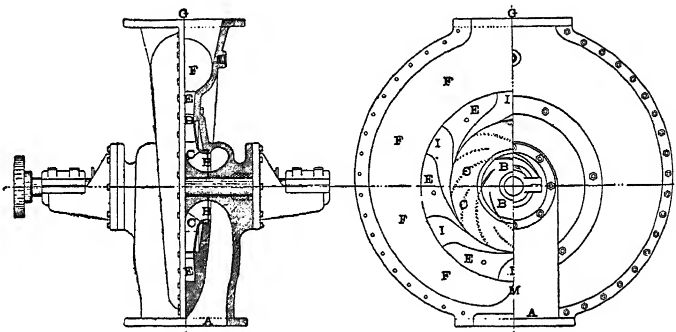


Fig. 97. Turbine Pump.

to the point of discharge is the most direct possible, which is a feature of great importance.

After leaving the suction opening, the water enters the impeller through an annular opening of ample area, and directed by the vanes is discharged at the desired velocity at the periphery of the impeller. The velocity of the water, which is highest at this point, is now gradually reduced by means of diffusion vanes designed in such a manner as to convert the velocity head of the water into static pressure with the minimum frictional loads. If the pump has only one impeller, the water on leaving the diffusion vanes passes into the discharge casing and thence to the delivery pipe. Fig. 97,



No. 2 No. 1

FIG. 98. TWINVOLUTE TURBINE PUMP.

however, shows a multi-stage pump, and in this case the water leaving the diffusion vanes of the first impeller passes in the most direct manner possible through the intermediate casing into the suction opening of the second impeller; this operation being repeated as often as is necessary to procure the final delivery pressure.

A new kind of turbine pump is the "twinvolute," which is built by Watson-Stillman Co., New York. These pumps are small, compact, heavily constructed, have but few parts, are subject to little wear and are highly efficient in operation. When the head is low the single-stage pump, which is provided with but a single revolving wheel, is used. As the head increases, the multi-stage pump, in which two or more impellers are used, is necessary. These pumps are built either horizontal or vertical, and they may be operated by gears, belt or an engine.

The single-stage twinvolute turbine pump is shown in Fig. 98

and consists of two similar castings which, when fastened together, form the case or shell in which the impeller rotates. The water enters through the flanged Y branch into the impeller eye equally in amount at the center and on each side. The pump body also carries the flanged suction and discharge openings, the shaft bearings and stuffing boxes. The shoulder of the pump body is held by the hood of the bedplate, which insures a good alignment and secure hold. By simply loosening a bolt the entire pump body may be placed in any desired position. The shaft is keywayed to receive the impeller and half coupling.

The water enters the suction opening *A* and passes in equal volumes through the Y branch channels to the inlet openings at the center on each side of the impeller *B*. Passing through the eye *B*, the water comes in contact with the arms *C*, which, when revolving, impart velocity to the water. Passing through the tips at the openings *D*, the water comes in contact with the diffusion vanes *E*, which change the kinetic energy of the fluid into pressure, gradually and without shock. The water enters the twinvolute chamber *F* and is discharged at *G*.

CHAPTER VII.

TRANSPORTATION OF GASES.

Wherever an admixture of steam to the gases to be conveyed is not objectionable, steam jet blowers, steam jet exhausters and steam jet ventilators are the most convenient apparatus that can be used. These three types are built by the Schutte and Koerting Co., Philadelphia.

The variety of application and the corresponding difference in the proportion of these instruments is without limit, depending on the variation of volume and counter pressure or the degree of rarefaction to be overcome. The limit of rarefaction is 25 inches of mercury, and the limit of counter pressure one seventh of the steam pressure of the actuating jet.

By regulation of the area of the actuating jet, as also by the regulation of the steam pressure, a variation within certain limits in the capacity and the general effect of the same instrument can be effected, so that instruments of certain sizes and dimensions can by a proper adjustment be made to be correct and most effective on varying conditions and for various purposes.

These air and gas blowers and exhausters are divided into two classes:

1. The machines for the purpose of overcoming a certain low counter pressure or rarefaction of, say, from ½ to 6 inches of water, which attain the desideratum of extreme volumes, are called blowers and ventilators.

2. Machines for the purpose of overcoming a high counter pressure, up to one seventh the steam pressure, or exhausting against a higher rarefaction of from 10 to 25 inches of mercury, attaining the desideratum of extreme pressures, are called compressers and exhausters.

Steam Jet Blower. Fig. 99 shows the steam jet blower with spindle. *A* is the air inlet, *R* the regulating spindle, *S* the steam connection, *M* are the nozzles. To obviate or reduce the noise caused by the action of the blower, an air conduit *C*, as shown in Fig. 101, should be attached to the top of the instrument, leading

straight up to or extending through the roof of the respective room to the outside. When this blower is used for blowing, attachment is made to bottom flange. When used for sucking, attachment is made to top flange. It can be placed vertical or horizontal.

The steam jet blower is effectively used in boiler firing for pro-

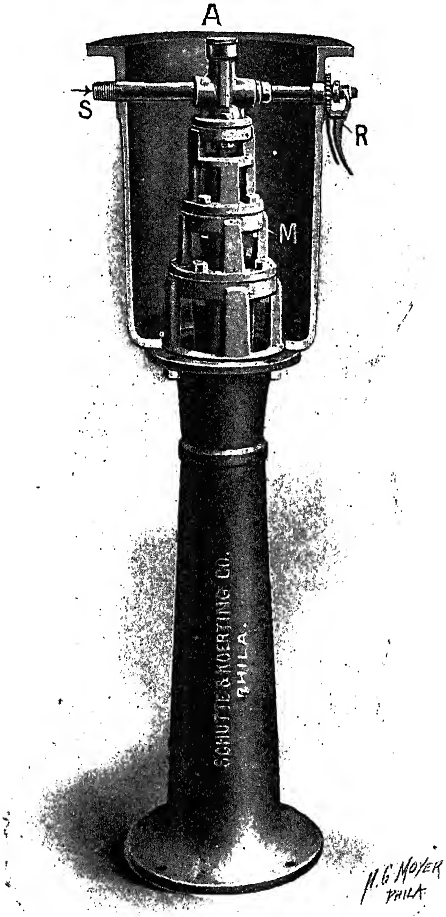


FIG. 99. STEAM JET BLOWER.

ducing a blast perfectly under control and at the least expenditure of steam. For small size and low grade fuels, and for furnaces with insufficient draft, this system is highly to be recommended. The blower also provides a means of forcing boilers to an evaporation beyond their rate of capacity, thereby obviating the necessity

of supplementary boilers in a case of emergency, which is especially desirable where boilers are used for short seasons only.

The application of this blower for transporting the air of combustion and steam to a producer is shown in Fig. 100. *T* is the

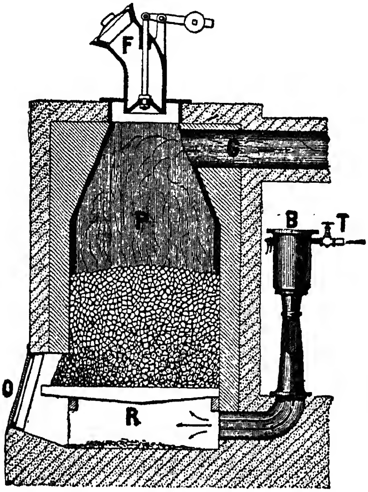


FIG. 100. STEAM JET BLOWER CONNECTED TO PRODUCER.

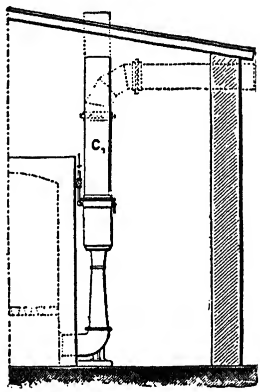


FIG. 101. OBVIATING NOISE OF STEAM JET BLOWER.

steam valve, *B* the air inlet, *O* the fire door, *P* the producer, *F* the hopper, *G* the gas outlet.

Fig. 101 shows the arrangement of an air conduit *C* to obviate or reduce the noise caused by the action of the blower.

Fig. 102 shows the application of a blower as ventilator. In this

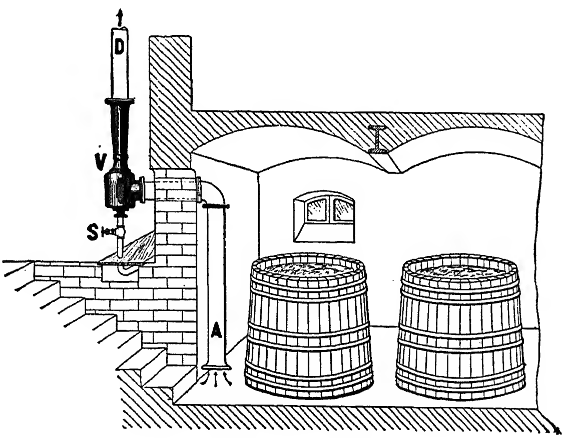


FIG. 102. BLOWER AS VENTILATOR.

case the moving power is also a steam jet issuing from a nozzle, which, traversing others of larger diameter, draws the air and carries it along, imparting a certain velocity to same. Foul air to be removed may be drawn through pipes and conduits from any locality or forced to wherever required. In the illustration shown the foul air enters into pipe *A* and leaves through pipe *D*. *V* is a steam jet blower, *S* is the steam valve.

This system can be applied for ventilating mines, shops, ships, etc. Also for temporary work, such as during the sinking of shafts, deep wells, etc., and also for removing the vapors from drying rooms. The steam jet blower is also applied to Cowper stoves to draw air through for cooling them down rapidly, when operations are discontinued.

Chimney Ventilators or Blast Nozzles. These instruments are also operated by the steam jet and are successfully used for improving the chimney draft in industrial furnaces or ovens. They belong to the class of jet apparatus, which have a series of nozzles of increasing areas, in which the motive power of a small jet of

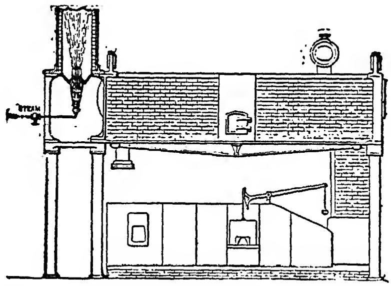


FIG. 103. NOZZLE ATTACHED TO STACK.

steam is thoroughly utilized, to move the gases to be dealt with. In the proper construction of the nozzles is to be found the reason of these ventilators combining satisfactory results with greatest economy.

Fig. 103 shows a nozzle attached to the stack of a heating or puddling furnace for increasing the draft. For this purpose these ventilators must be placed in the middle of the chimney, just above the entrance of the main flue. All sharp corners at the entrance of the main flue into the chimney must be beveled at an angle of 45 degrees.

When the chimney ventilator replaces a chimney it is put over

the main flue upon a brick foundation covered with a cast-iron plate. The ventilator is fixed upon this plate with the flange of its largest nozzle. Before connection is made, the steam pipe must be thoroughly cleaned out with high-pressure steam, to prevent dirt or grit getting into the nozzles of the ventilator. This apparatus does not need any steam, when the fire is being started. To stop the action of the ventilator the steam valve is closed. These nozzles are also made of lead.

Steam Jet Exhausters. For the chemical and metallurgical industries the lead exhausters of this type are of the greatest interest. They are constructed with side inlet for gas, and removable end covers to facilitate the removal of inside parts without disturbing connections. To give strength and wear to the steam nozzle it is lined with platinum or other desirable metal, or with hard rubber, to suit requirements.

Fig. 104 shows an application of this apparatus for moving gases.

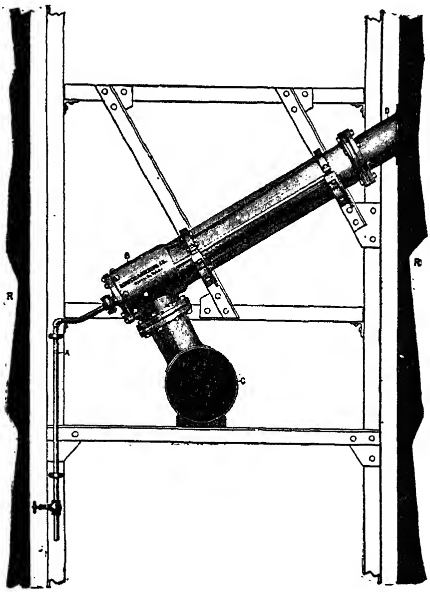


FIG. 104. STEAM JET EXHAUSTER.

A is the steam supply pipe; *B* the lead exhauster and blower; *C* the gas supply pipe; *R* is the chamber to which the gas is transported.

Fig. 105 illustrates the application of an exhauster of this type in the manufacture of a solution of sulphurous acid. *E* is the ex-

hauster; *F* the sulphur furnace; *G* the tank. The admissible vacuum and counter pressure to which this apparatus is constructed is a rarefaction up to 20 inches of mercury or a counter pressure up to one seventh of the steam pressure. These exhausters may be placed horizontal or vertical, discharging upwards, downwards or

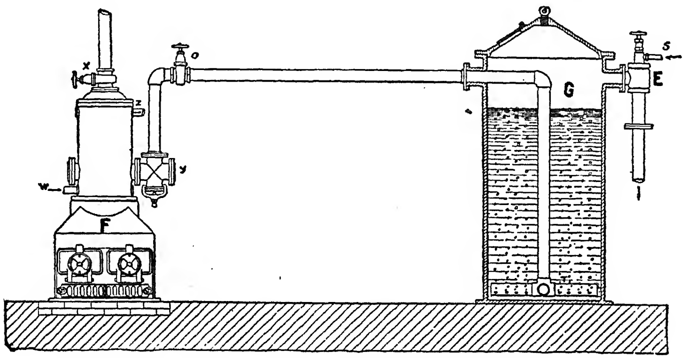


FIG. 105. APPLICATION OF STEAM JET EXHAUSTER.

horizontally. Traps in both the suction and discharge pipe must be avoided.

Gas Montejus. A gas compressor with liquid piston, which is built by the Schutte and Koerting Co., Philadelphia, Pa., and is constructed on the same principle as the automatic montejus, of which a detailed description is found in the chapter "Transportation of Liquids," is illustrated in Fig. 106. As this apparatus can be built of lead, cast iron or any suitable material, it is especially adapted for the compression of such gases which attack the materials used in the ordinary compressors.

Steel-plate Fans. These fans are usually used where it is desired to handle large volumes of air at a moderate velocity, as a rule not exceeding $1\frac{1}{2}$ oz. per square inch pressure. They are designed to deliver a maximum amount of air with a minimum expenditure of power. Upon the design of scroll of the housings and the relative proportions of the blast wheels, together with its form, depends not only the amount of air per horse power the steel-plate fan is capable of delivering, but its quietness of operation. Inlets and outlets of a fan play a most important part in the question of economy of power. It will be readily seen, therefore, that it is a matter of vital importance that these details be perfectly in proportion. The standard proportions of steel-plate fans described below, which are manu-

factured by the Buffalo Forge Co., Buffalo, N. Y., have been adopted as the outcome of a series of experiments extending over a number of years with machines in actual use.

These steel-plate fans are built of homogeneous patent leveled and rolled steel sheets, free from buckles and of the greatest stiffness. The fan cases are rigidly stayed by angle irons to prevent vibration. Base angle iron foundation frames are supplied. The

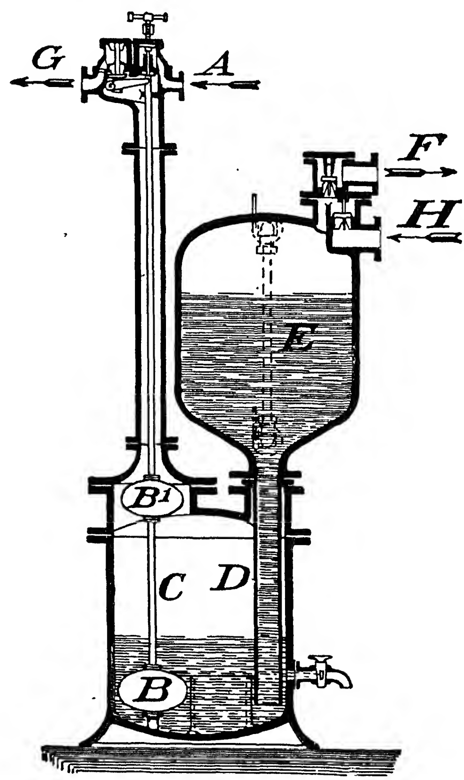


FIG. 106. GAS MONTEJUS.

bearing brackets are bolted to heavy steel angle irons and the bearings are swiveled to prevent springing of the shaft when the machine is bolted to a defective foundation; they are equipped with ring oiling bearings, having large wearing surfaces lined with genuine babbitt. The shafts are of cold rolled steel of large diameter.

These fans are regularly built both right or left hand, and to deliver air in any of the following forms: bottom horizontal, top horizontal, up blast and down blast. They may be readily furnished

in all sizes to discharge in any one or two angles to suit all conditions of application. A very simple solution to an otherwise diffi-

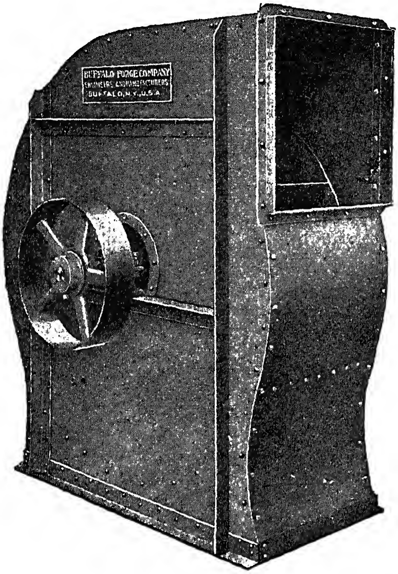


FIG. 107. PULLEY DRIVEN STEEL PLATE FAN.

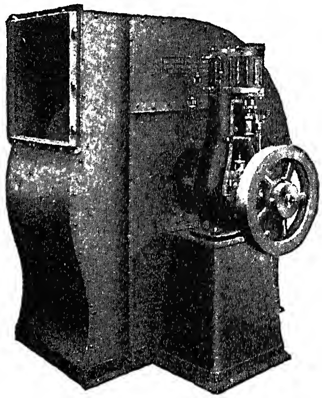


FIG. 108. SPECIAL DISCHARGE FAN WITH DOUBLE ACTING ENGINE.

cult problem is often found by using a special double discharge fan (Figs. 107, 108, 109).

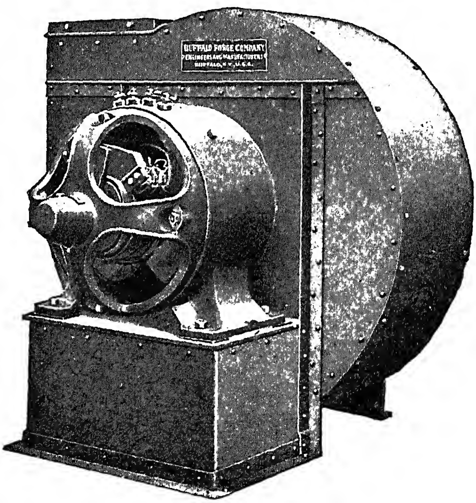


FIG. 109. MOTOR DRIVEN STEEL PLATE FAN.

Acid-proof Fans. In case it is desired to handle gases with the steel-plate fan, which not only must not escape even in small quantities, but which will have a chemical action on the fan itself, a lead-lined steel-plate blower or exhauster is made by the Buffalo Forge Co. with a cast-iron blast wheel and having flanged outlet and inlet, together with a packed shaft, to insure an absolutely tight outfit. This type of machine is illustrated in Fig. 110. For strongly acid

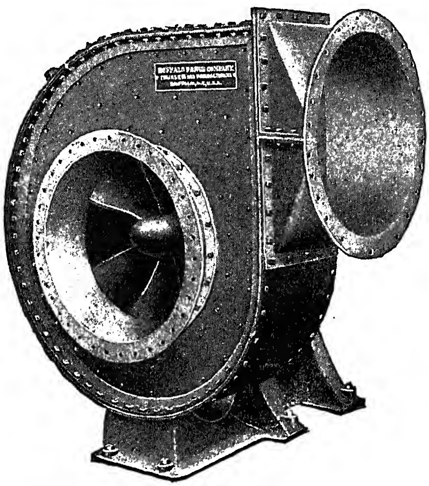


FIG. 110. LEAD LINED GAS EXHAUSTER.

gas a cast-iron gas exhauster (Fig. 110 *A*) is built by the same firm.

A rotary lead fan, which is built by the Schutte and Koerting Co., Philadelphia, is shown in Fig. 111. An installation of this machine at the head of a system in a sulphuric acid plant is illustrated in Fig. 112.

All of these acid-proof fans and exhausters are essential for installations where a regular and constant draft is to be maintained under all conditions.

Steel Pressure Blowers are designed and built by the Buffalo Forge Co. to withstand the strains of high-pressure duty. For supplying blast to cupolas, furnaces, forge fires, sand-blast machines, and for any work where air is to be forced for a long distance, as in pneumatic-tube systems, their utility needs no demonstration.

The manner in which these blowers are constructed, and in which the bearings are affixed, adapts the machine for standing up under

continuous high-pressure service. A distinguishing feature of the construction is the solid peripheral shell, with the side plates securely fastened thereto. This allows a tight fit to be made, resulting in a blower of maximum strength and rigidity, greatly superior to those formed with a central putty joint. The long, adjustable bearings,

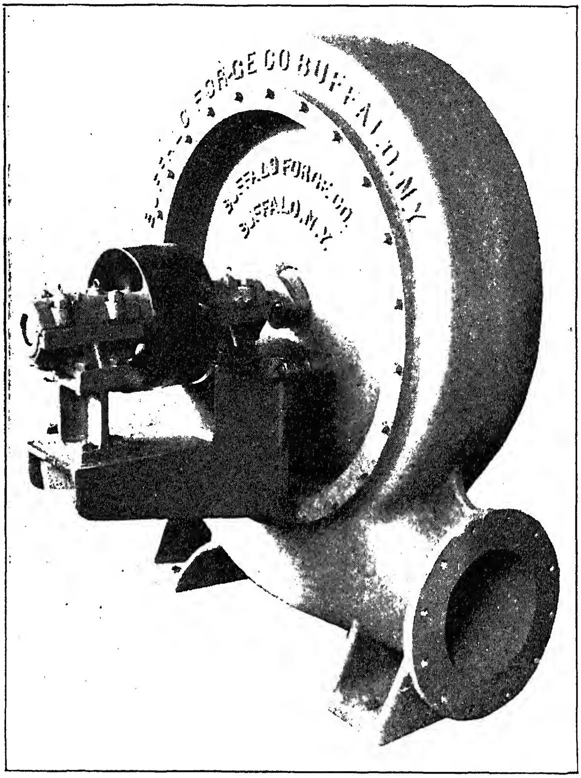


FIG. 110A. CAST IRON GAS EXHAUSTER.

of the standard Buffalo oil-ring type, are so carried as to preclude any possibility of incorrect alignment.

Buffalo Compound Turbine Blowers. Though the scheme of compounding two or more stages in centrifugal pump design has been commonly resorted to by manufacturers to effect reduction in peripheral speed the idea has not been applied—in more than an experimental way at least—to centrifugal blowers. The principle of the design which allows a culminative pressure to be effected at the outlet rests on the fact that with a given design of wheel casing

and peripheral speed a fan will accomplish a certain number of ounces increase in pressure between the inlet and that in the discharge pipe. With two stages and a given diameter of wheel double the pressure can be obtained with the same speed necessary with only a single stage and blast wheel (Fig. 113).

"B" Volume Blowers and Exhausters. This type of blower is

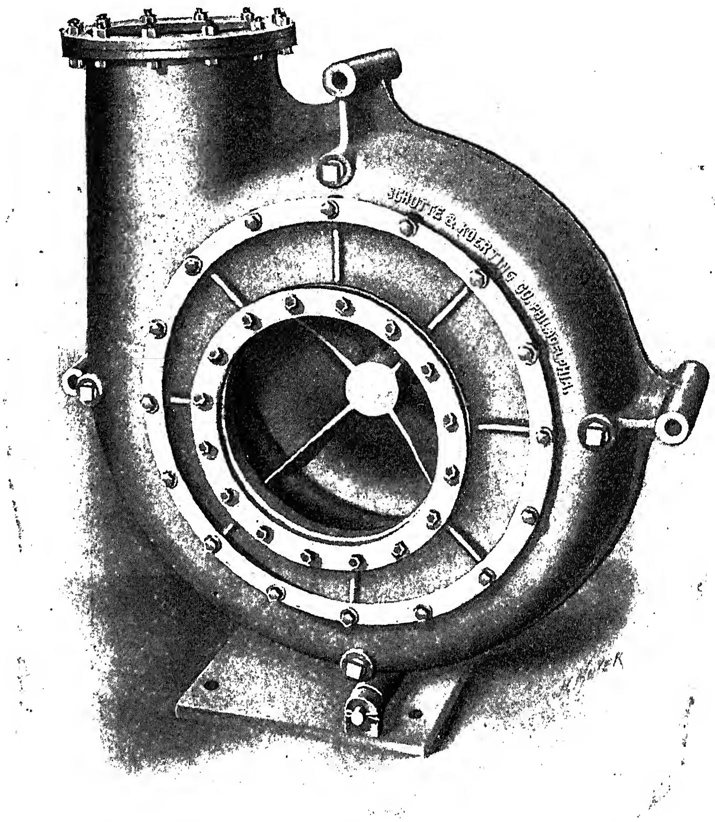


FIG. 111. LEAD LINED FAN.

designed for larger capacities at lower pressures than the steel pressure blower. It makes a neat, compact, strong and highly efficient machine for installations where large capacities and small pressures are required and yet where a well designed steel-plate fan would be found to have too large a capacity. The more important uses are in forge shops, and supplying forced draft for boilers. The ex-

hausters which are built with overhung wheels making a free fan inlet meet the requirements of small outfits for the removal of refuse

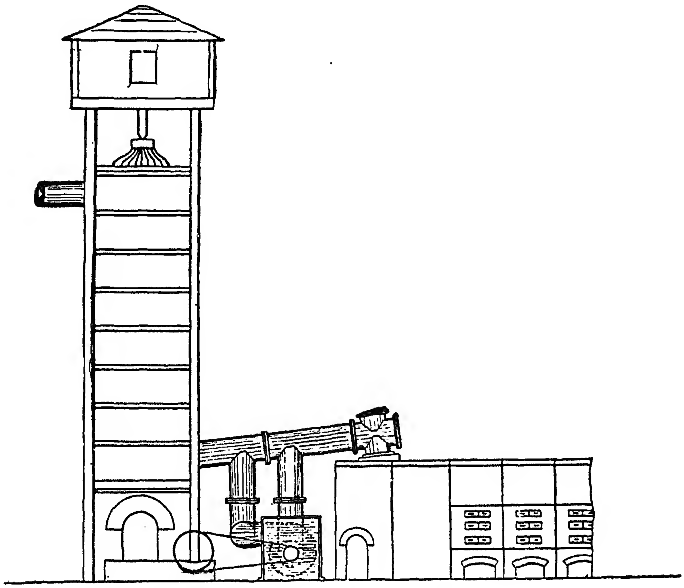


FIG. 112. FAN AT HEAD OF SYSTEM.

from emery wheels, buffing wheels, or the machines of any abrasive processes, also for removing smoke in forge shops.

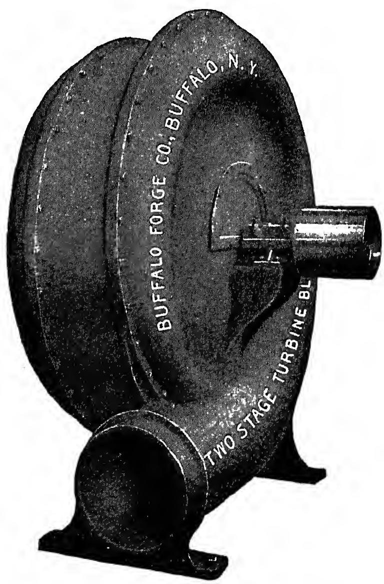


FIG. 113. COMPOUND TURBINE BLOWER.

The general design is the result of long experimenting to determine the most efficient form and the structural details conforming to the highest standard of machine-shop practice. To the solid outer shell, which carries likewise the discharge orifice, are securely bolted two side plates, in which are formed the inlets or the inlet as the case may be. The bearings, which are so affixed as to insure perfect alignment, are of the standard Buffalo ring-oiling type, the excellent design of which enables the blowers to be run at continuous high speeds with but very little attention.

Where it is necessary to have an absolutely tight blower or exhauster, such as when handling gases, the Buffalo "B" volume blower is fit with flanged connections and packed shaft, as shown in the illustration (Figs. 114, 115).

Buffalo steel-plate planing mill exhausters are constructed of heavy

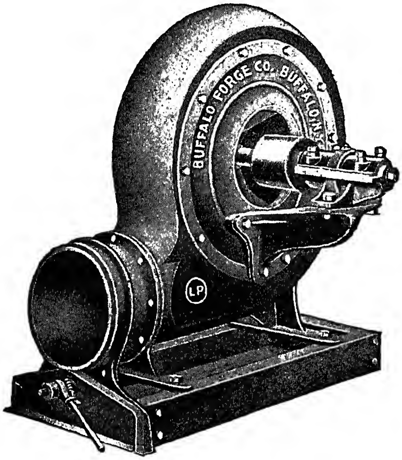


FIG. 114. STANDARD B VOLUME BLOWER.

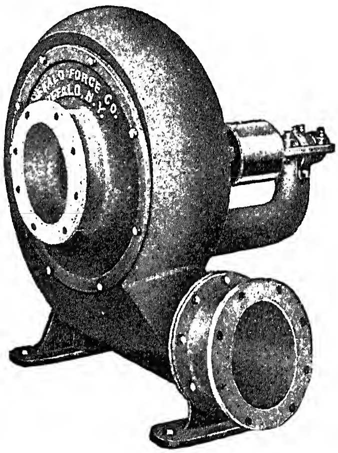


FIG. 115. "L. P." GAS EXHAUSTER.

steel plate, firmly braced and stiffened with angle irons. A heavy cast-iron pedestal entirely independent of the fan shell carries the pulley wheel and the improved ring-oiling bearings. These fans, of course, are built as exhausters, or in other words, with a single inlet orifice and overhung blast wheel. The latter consists essentially of a cast-iron hub, wrought-iron spider arms, conical side plates and steel-plate blades with backwardly curved tips, and is built with the greatest rigidity. When the material to be handled contains shavings of a long stringy nature, it is customary to provide a blast wheel specially constructed so as to prevent clogging of the blades. Ex-

haust fans for handling the refuse from emery grinding are built with wheels and shell of extra heavy material.

As indicated by the name of this special type of steel-plate fan, the most common application is for the purpose of exhausting shavings, sawdust and refuse from wood-working machines of all types.

For the purpose of exhausting the dust from emery wheels, buffing wheels and from the machines employed in various abrasive processes, the Buffalo steel-plate planing mill exhaust fan is of the greatest utility. In the special case of emery exhausting, both the blast wheel and fan are constructed of heavy stock, in order to with-

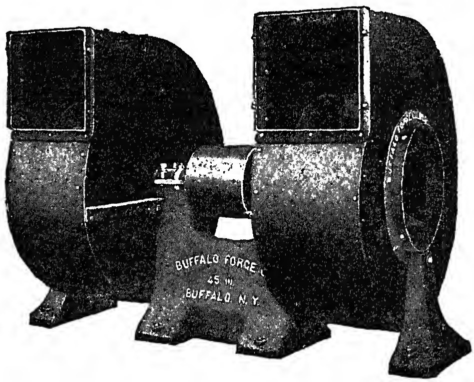


Fig. 116. Steel Plate Planing Mill Exhauster.

stand the wearing effect on the same. In no case should the same fan be employed to handle refuse from buffing machines and emery wheels.

These exhaust fans are frequently employed in forge shops in conjunction with the Buffalo down-draft system of forge construction for the purpose of withdrawing the smoke and gases. In this system, all the piping, both blast and exhaust, is placed underground, affording practical indestructibility. Still another application that may be noted is the handling of cotton, wool and other textiles, as well as spent tan-bark in tanneries. The installation of such fans for the purpose of elevating and conveying cotton often proves of the greatest convenience and saving. Other uses of the same nature there are, too numerous to be mentioned here (Fig. 116).

Ventilating. Buffalo disk wheels are the product of a demand for a simple yet effective means of ventilating, cooling and drying in numerous situations.

The form of the Buffalo disk-wheel was adopted after exhaustive experimenting to determine the most efficient pattern, and as a direct consequence of this the power consumption for moving any given volume of air is a minimum for this style of fan. The circumferential scroll is of heavy steel plate, reinforced with cast-iron rims and brackets supporting the two bearings. These are of ample length, lined with the best babbitt and furnished with adequate lubricating devices. The steel-plate fan blades are bolted to the wrought-iron spider arms, which in turn are rigidly fastened to the cast-iron hub. An accurate running balance of the wheel, as well as perfect rigidity of the whole machine, are features of importance. The high standard attained by Buffalo disk wheels is due, therefore, to perfection of design, material and construction.

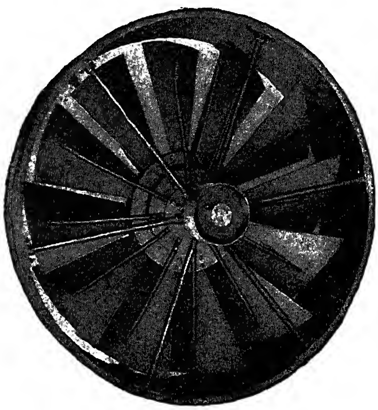


FIG. 117. PULLEY DRIVEN DISK WHEEL.

These disk wheels deliver air in a direction parallel to the axis of rotation and are unexcelled for all situations to which this type of fan is adapted. Among other applications, Buffalo disk wheels are widely used for ventilating. In addition to such use in all manner of buildings, these wheels have proved themselves of the greatest value to numerous industries, and indeed the variety of service to which they may be put is almost endless. In all cases where it is desired to effect a movement of air or vapor at moderate velocities with a minimum expenditure of power, Buffalo disk wheels will be found to fully meet every requirement (Fig. 117).

Air Compressor. A very important appliance for conveying air or other gases at atmospheric or higher pressure is the air compressor. For heavy duty the "straight line" type of machine which is built by the Ingersoll Rand Company, New York, is successfully used. It embodies the following features: positive movement of the air valve; cold intake air; cooling by complete surface jacketing; small clearance spaces; automatic regulation of speed and air pressure; high rotative speed; large bearing surfaces for shaft, crank

pins and cross head; automatic and copious lubrication of every bearing surface. Fig. 118 shows the details of the piston inlet air cylinder of this machine. *A* is the circulating water inlet; *B* the circulating water outlet; *C* the water jacket drain pipe; *D* the oil hole for automatic oil cup; *E* the air inlet; *F* the air discharge; *G* the piston inlet valves; *H* the discharge valve; *J* the water jacket. Cold air is always passing through the ports, the tube is part of the

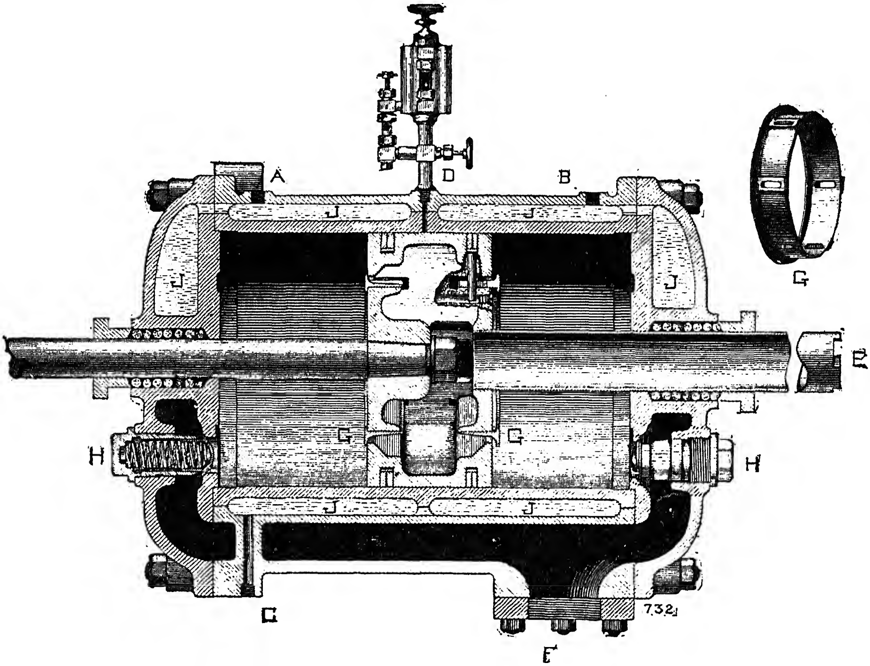


FIG. 118. DETAILS OF PISTON INLET AIR CYLINDER.

time outside, always surrounded by water-jacketed packing. Only the skin surface of the solid entering air body comes in contact, and then only for one fourth part of a second. Hence the tube, the piston and the valve are kept cool.

Vacuum Pump. For the operation of vacuum evaporators, vacuum dryers, etc., the proper construction of the vacuum pump is of importance. A vacuum pump is really an air pump and differs only from an ordinary air compressor which compresses from atmospheric pressure to some higher point, in that it begins at say 28 inches of vacuum and compresses to atmospheric pressure. To insure the opening of the valve at the proper time and to permit a relatively high speed of rotation the valve has to be mechanically

operated. A sufficient cooling by means of water jackets is also of importance. Fig. 119 shows a vacuum pump built by the Alberger Condenser Co., New York, in which all possible loss by friction is avoided and the ports and passages made especially large and direct. The detrimental influence of the clearance space is nicely prevented

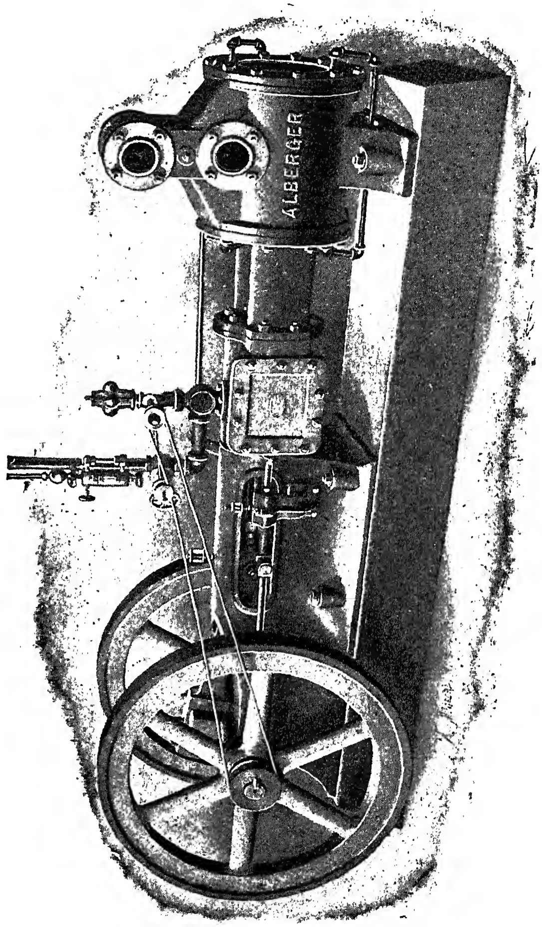


FIG. 119. VACUUM PUMP.

by the use of an equalizing port in the body of the mechanically operated valve, which, when the piston is at the end of the stroke, connects the clearance space in front of the latter, with the cylinder space behind it. The piston, on reaching the end of the stroke, has in front of it that air at atmospheric pressure which has not been discharged during the stroke through the outlet valve. By means

of the valve arrangement mentioned, however, the enclosed air is removed into the clearance space before the piston begins its return stroke, whereby the efficiency is greatly increased. For producing the highest possible degree of vacuum two-stage vacuum pumps are used.

Positive Pressure Blower. For transporting large quantities of air at high pressure the positive pressure blowers are widely used in the chemical and metallurgical industries. Fig. 120 shows a machine

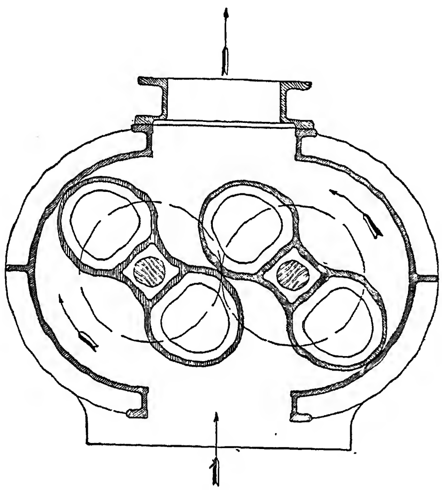


FIG. 120. POSITIVE PRESSURE BLOWER.

built by the Connersville Blower Company. In these types the air is enclosed by the motion of the impellers into a space formed by the impellers and the casing, and is transported to the outlet opening. The working of this machine is so simple and is so well known that a detailed description is not necessary.

Chimneys. Chimneys are required for two purposes: First, to carry off obnoxious gases; second, to produce a draft, and so facilitate combustion. The first requires size, the second height.

Each pound of coal burned yields from 13 to 30 pounds of gas, the volume of which varies with the temperature.

The weight of gas to be carried off by a chimney in a given time depends upon three things—size of chimney, velocity of flow, and density of gas. But as the density decreases directly as the absolute temperature, while the velocity increases, with a given height, nearly as the square root of the temperature, it follows that there is a

temperature at which the weight of gas delivered is a maximum. This is about 550° above the surrounding air. Temperature, however, makes so little difference, that at 550° above, the quantity is *only four per cent.* greater than at 300°. Therefore, height and area are the only elements necessary to consider in an ordinary chimney.

The intensity of draft is, however, independent of the size, and depends upon the difference in weight of the outside and inside columns of air, which varies nearly as the product of the height into the difference of temperature. This is usually stated in an equivalent column of water, and may vary from 0 to possibly two inches.

After a height has been reached to produce a draft of sufficient instensity to burn fine, hard coal, provided the area of the chimney is large enough, there seems no good mechanical reason for adding further to the height, whatever the size of the chimney required. Where cost is no consideration there is no objection to building as high as one pleases; but for the purely utilitarian purpose of steam making equally good results might be attained with a shorter chimney at much less cost.

The intensity of draft required varies with the kind and condition of the fuel and the thickness of the fires. Wood requires the least, and anthracite screenings the most. The strong draft required for burning the smaller sizes of anthracite coal necessitates a very tall chimney unless forced blast is used.

Generally a much less height than 100 feet cannot be recommended for a boiler, as the lower grades of fuel cannot be burned as they should be with a shorter chimney.

A round chimney is better than square, and a straight flue better than a tapering, though it may be either larger or smaller at the top without detriment.

The effective area of a chimney for a given power varies inversely as the square root of the height. The actual area, in practice, should be greater, because of retardation of velocity due to friction against the walls. On the basis that this is equal to a layer of air two inches thick over the whole interior surface, and that a commercial horse power requires the consumption on an average of 5 pounds of coal per hour, we have the following formulas:

$$E=(0.3H/\sqrt{h})=A-0.6\sqrt{A} \qquad (1)$$

$$H=3.33E\sqrt{h} \qquad (2)$$

$$S = 12\sqrt{E} + 4 \qquad (3)$$

$$D = 13.54\sqrt{E} + 4 \qquad (4)$$

$$h = (0.3H^2/E) \qquad (5)$$

in which H = horse power; h = height of chimney in feet; E = effective area, and A = actual area in square feet; S = side of square chimney, and D = diameter of round chimney in inches.

To find the draft of a given chimney in inches of water: *Divide 7.6 by the absolute temperature of the external air* ($\tau_a = t + 460$); *divide 7.9 by the absolute temperature of the gases in the chimney* ($\tau_c = t' + 460$); *subtract the latter from the former, and multiply the remainder by the height of the chimney in feet.* This rule, expressed in a formula, would be:

$$d = h(7.6/\tau_a - 7.9/\tau_c).$$

To find the height of a chimney, to give a specific draft power, expressed in inches of water: *Proceed as above, through the first two steps, then divide the given draft power by the remainder*, the result is the height in feet. Or, by formula:

$$h = \frac{d}{\frac{7.6}{\tau_a} - \frac{7.9}{\tau_a}}$$

To find the maximum efficient draft for any given chimney, the heated column being 600° F. and the external air 62°: *Multiply the height above grate in feet by .007, and the product is the draft power in inches of water.*

The external diameter of a brick chimney at the base should be one tenth the height, unless it be supported by some other structure. The "batter" or taper of a chimney should be from one sixteenth to one fourth of an inch to the foot on each side.

Thickness of brick work: one brick (8 or 9 inches) for 25 ft. from the top, increasing one half brick (4 or $4\frac{1}{2}$ inches) for each 25 ft. from the top downwards.

If the inside diameter exceed 5 ft. the top length should be $1\frac{1}{2}$ bricks, and if under 3 ft. it may be one half brick for ten feet.

CHAPTER VIII.

GRINDING.

The grinding of raw materials and finished products is of such importance for the industries that the selection of the proper construction has to be made with the greatest care. It depends upon the nature of the material to be handled, the capacity required and the fineness desired, what kind of mill is to be used. The selection of one of these machines is greatly facilitated by the experimental stations which are installed in the shops of nearly all the large manufacturers of mills and are at the disposal of the customers.

Generally speaking, the grinding appliances can be divided into

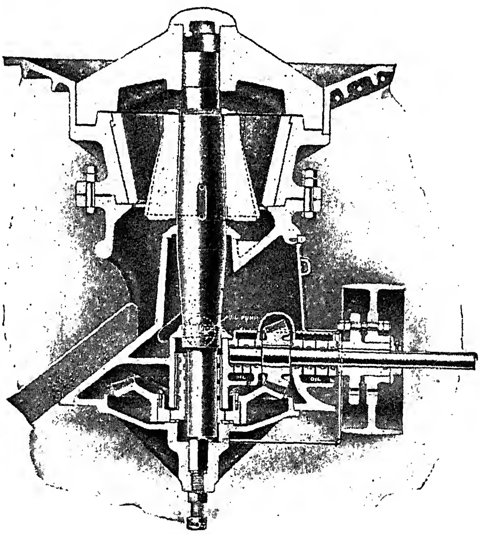


FIG. 121. GYRATORY CRUSHER.

machines for crushing and coarse grinding and in machines for the production of a fine powder.

Gyratory Crushers. The gyratory type shown in Fig. 121, which is used in almost all the cement mills and other industries, consists essentially of a vertical spindle, on the upper end of which is mounted a chilled iron crushing head that moves inside a hopper-

shaped top, into which the rock is fed. The bottom of the spindle passes loosely through an eccentric, driven from a horizontal shaft by bevel gears. The spindle, therefore, has a gyratory motion, and may or may not rotate on its own axis. As the head, running eccentrically, approaches and recedes from the side of the hopper, the stone is gradually crushed and falls down between the crushing surfaces. The stone must be broken by hand to a convenient size to feed into the hopper. A crusher having a hopper about 40 inches in diameter and a crushing head about 20 inches will have a stroke of approximately $\frac{5}{8}$ inch.

The horse power necessary to drive averages 1.2 times the tons of rock crushed by hour, figuring on rock of moderate hardness. A crusher of this type is suitable for individual belt drive. Sometimes two or more crushers are belted to one motor, though this is not the best practice, as all crushers must be stopped when the motor is shut down. Gearing is not suitable for these machines, as the driving gear would be subject to a severe strain should the crusher become clogged with rock.

Crushing Rolls. These machines are built with plain or corru-

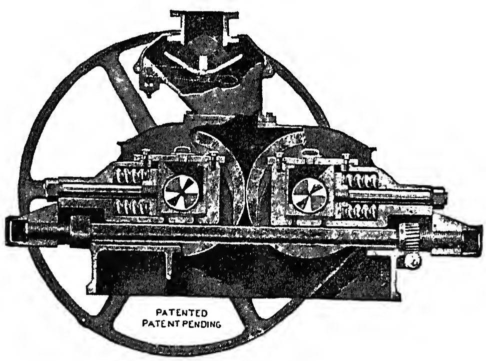


FIG. 122. CRUSHING ROLL.

gated rolls. Their construction is easily understood from Figs. 122 and 140.

Jaw Crushers. In this type the pressing force of a moving jaw is utilized for crushing the material. This is a simple and effective crusher of moderate cost, capable of crushing the hardest material. It is illustrated in Fig. 123.

Open-door Crushers. The open-door rotary fine crusher shown

in Fig. 124 is built by the Sturtevant Mill Co., Boston, Mass., in capacities from 1,000 pounds to 35 tons per hour. In this mill, which is widely used for soft and moderately hard materials, every

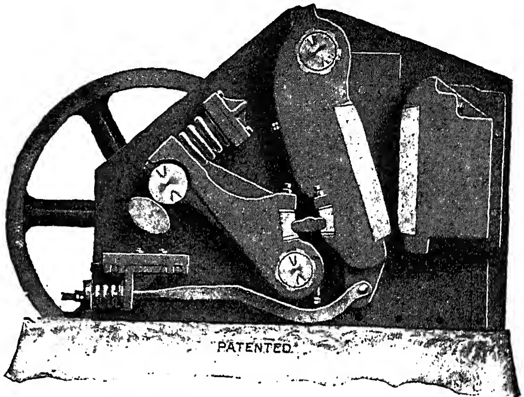


FIG. 123. JAW CRUSHER.

part of the interior is easily accessible for replacement and inspection.

Stamp Mills. The stamp mill shown in Fig. 125 is about the oldest and, for certain materials, the most convenient crushing

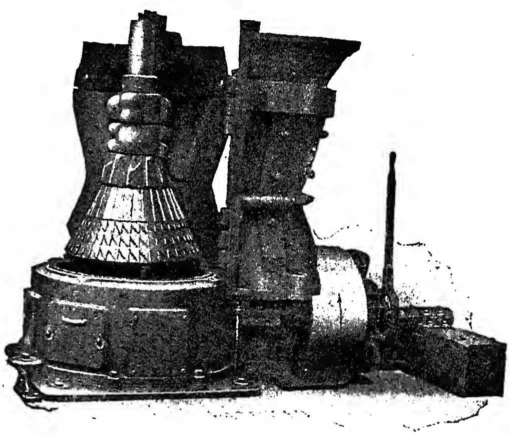


FIG. 124. OPEN DOOR CRUSHER.

machine, as it does not come out of order and requires very little attendance.

Disintegrator. A pulverizing machine of great capacity, especially adapted for operations where it does not matter if part of the

material is not ground to the greatest fineness, is the disintegrator shown in Figs. 126 and 127. This mill, which is built by the Kent Machine Co., Brooklyn, N. Y., is used for reducing to powder such substances as borax, alum, sulphur, paris white, whiting, litharge, glue, gums, rosin, sugar, starch, potash, dry colors, etc.; also for mixing together dry materials, as fertilizers, dry colors, etc. This machine is of very simple construction and can be operated by unskilled labor. It consists of four steel cages running at a very high speed in opposite directions. The material is fed into the center of the machine through the hopper shown, and the centrifugal force

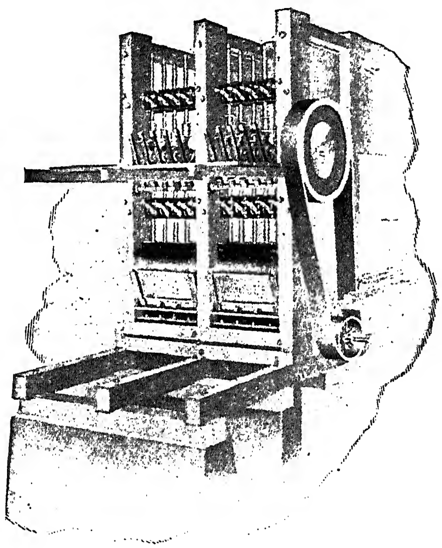


FIG. 125. STAMP MILL.

is such as to drive it out through the steel bars, which, going at the speed they do, and in opposite directions, pound the material to powder.

Chaser. For crushing lumpy materials in a dry or semi-dry state, such as oxide of copper, glass, etc., and for mixing white lead, mortar, etc., the chaser shown in Fig. 128 is used. This machine, which is manufactured by the Kent Machine Works, Brooklyn, N. Y., is strongly and substantially built, and is complete and self-contained. Both pan and runner are cast iron turned smooth. The material is discharged through a gate in the side of the pan, in

which scrapers are so arranged that they will discharge the finished product while the machine is running.

A similar construction is the Chilean mill, which is widely used in the metallurgical industries. In this type the pan revolves, while the runner does not change its place, revolving only around its own center.

Stone Mills. For fine grinding of dry and wet materials the stone mills are exceedingly adapted. They generally consist of two

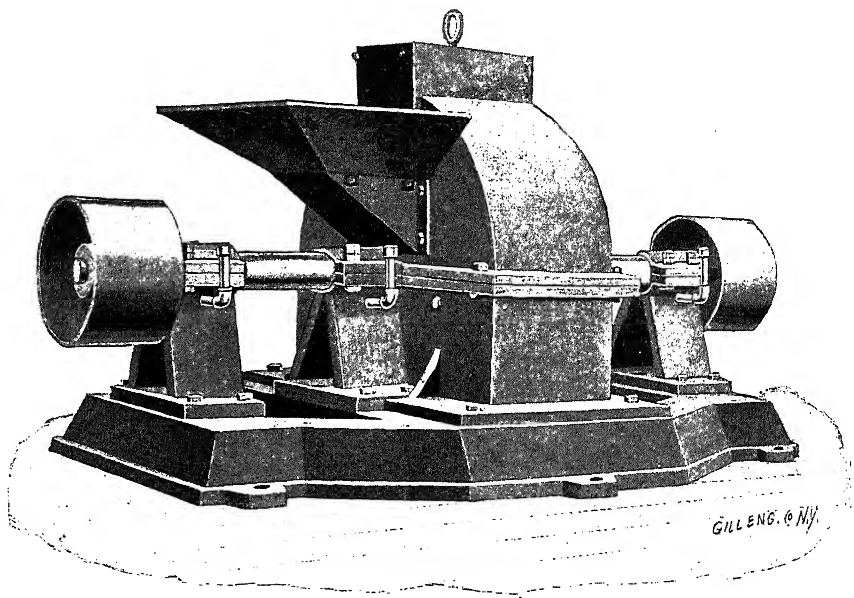


FIG. 126. DISINTEGRATOR.

horizontal stones (either top or bottom runner, with or without cooling). The material to be ground is fed to the mill from a hopper on top of same and is transferred by centrifugal force to the effective part of the stone.

Some of the most excellent mills of this type are built by the Kent Machine Co., Brooklyn, N. Y. Fig. 129 shows a group of three modern water-cooled mills, mounted on a cast-iron bedplate, driven with one counter-shaft, each mill being provided with a friction clutch, so they may run collectively or independently. The mixer pot on top of each mill is of cast iron and fitted with a stirring device.

Fig. 130 illustrates a modern grinding mill for lead and heavy paste. This machine is built by the above concern with either Buhr

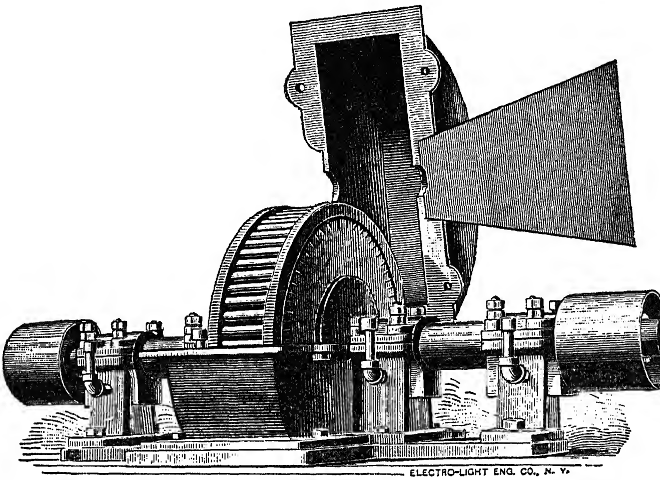


FIG. 127. DISINTEGRATOR SHOWING INTERIOR MECHANISM.

or Esopus stones, either plain- or water-cooled. The top stone is hinged and adjustable, and fitted with a hopper if desired.

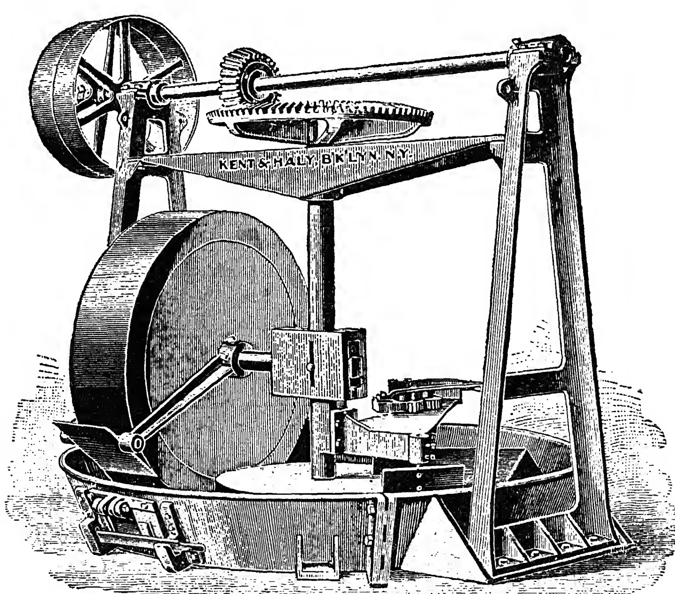


FIG. 128. CHASER.

Fig. 131 shows the tandem mill for grinding leads and heavy pastes. These mills are built water-cooled with Esopus or Buhr stones and are furnished single or in groups of three, mounted on a heavy cast-iron bedplate, a group of three comprising six mills in all.

When built in groups of three, an especially designed skew bevel

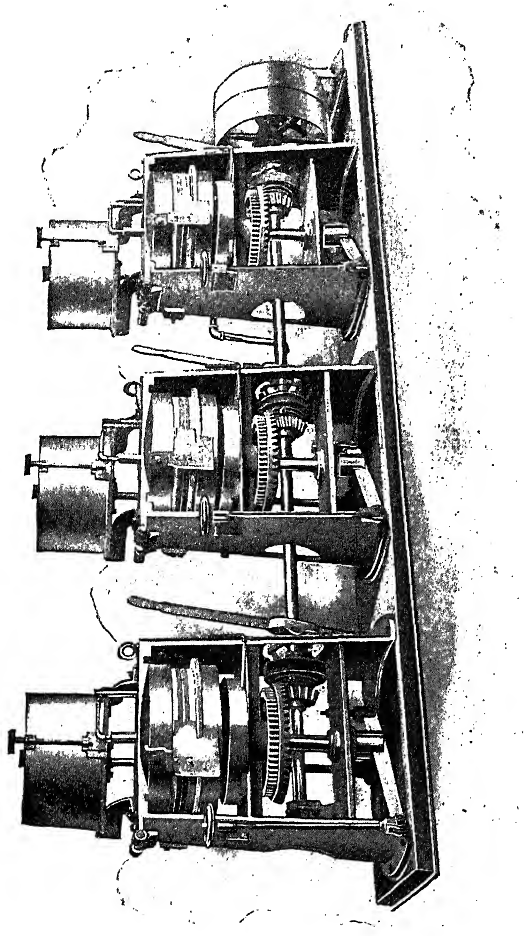


Fig. 129. Group of Three Water Cooled Mills.

gear is used for operating each mill. Each mill is also driven with a friction clutch, so that they may be run independently or collectively. Feed pots are also provided, if required.

Ball Mills. In cement works these mills take the output of the crushers and reduce it to a coarse grit. The mill consists of a drum,

having a diameter of about double its length, filled with steel balls. The drum revolves on a horizontal axis, at a speed of from 21 to 27 revolutions per minute. The lining of the drum is made up of overlapping steel plates, which form steps. As the drum revolves, the balls drop over the steps, pounding the material to pieces.

Tube Mills. The tube mill consists of a wrought-iron tube mounted as a shaft by the attachment of heads so formed as to make trunnions, which rest in bearings at both ends. A large gear

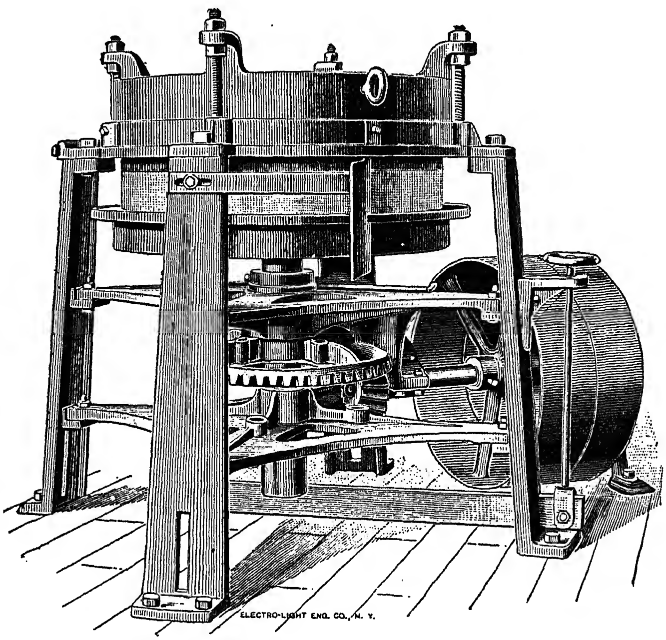


FIG. 130. GRINDING MILL FOR LEAD AND HEAVY PASTE.

attached to the tube and a pinion attached to the pulley shaft make the actuating device. The tube is lined with silex stone, and is about one half filled with flint balls. The enormous grinding surface thus provided permits of a very slow speed of rotation, 22 to 27 turns per minute, according to the size of the machines. The trunnion at the feed end is hollow, and a screw conveyor carries in the material. By simply regulating the feed, any degree of fineness, even to impalpable powder, may be obtained. Fig. 132 shows the tube mill built by F. L. Smidth and Company, New York.

Fig. 133 shows the spiral feed and discharge, which are the char-

acteristic features of the tube mill of the Abbé Engineering Company.

Kominuters. The kominuter is the latest development on the line of low-speed coarse grinders. It combines to some extent the best features of the ball mill and the tube mill, resulting in increased

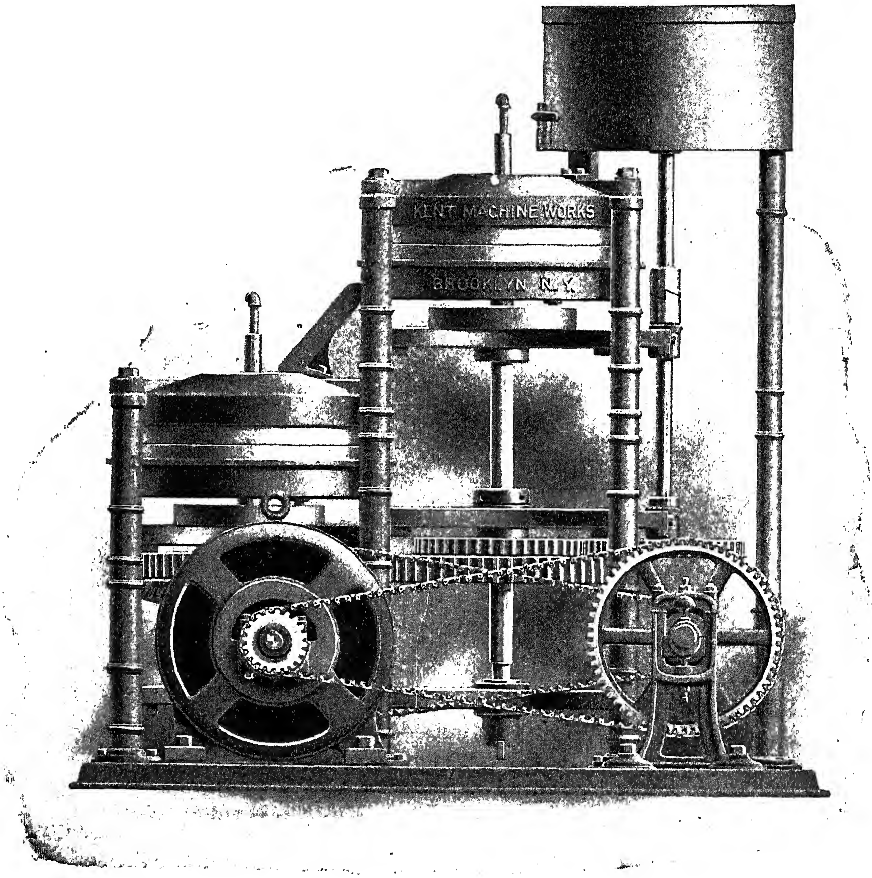


FIG. 131. TANDEM MILL.

capacity per horse power, and a decreased cost of repairs over ball mills; compared to a ball mill having the same volume of grinding room, and requiring approximately the same horse power, the kominuter can carry more balls than the ball mill; it has also more screen surface and of a higher efficiency per square foot than the ball mill, the wire cloth being the same in both cases. The kom

inuter gives a higher output per horse power than the ball mill, is self-contained, is provided with automatic feed, and automatically returns to the mill the tailings from the screens. Fig. 134 shows a kominuter built by F. L. Smidth and Co., New York.

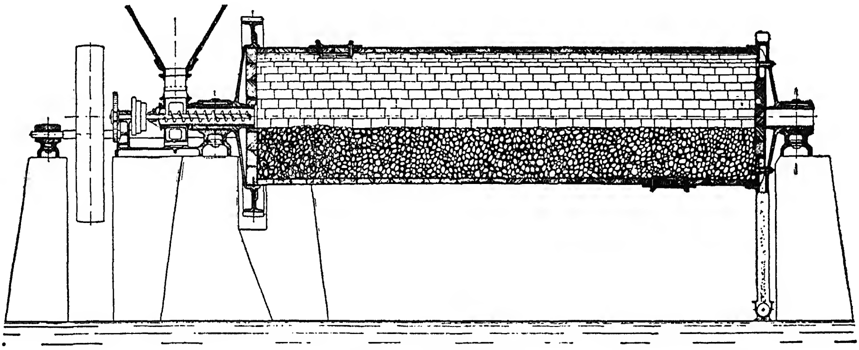


FIG. 132. TUBE MILL.

Griffin Mills. These mills are used for the fine grinding of cement and other materials. The mill shown in Fig. 135 is driven from a pulley at the top, revolving at a vertical axis. The power is transmitted to a vertical shaft, which is hung from a universal joint inside the pulley, and is free to move in any direction at the bottom. A crushing roll is rigidly connected to the bottom of the

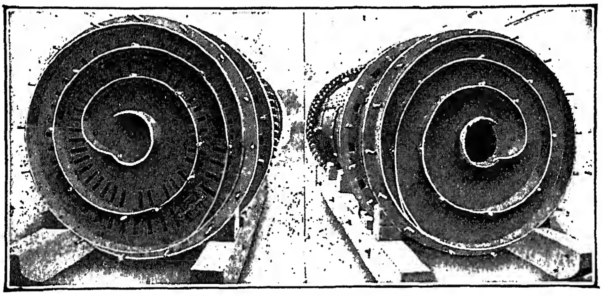


FIG. 133. SPIRAL FEED AND DISCHARGE.

shaft. When the pulley revolves the crushing roll is thrown off center, and revolves against a fixed ring or die with a centrifugal force of about six thousand pounds pressure. The grinding is done between these two surfaces. Two distinct actions on the material to be ground are obtained; the roll revolves against the die in the direction of the pulley, and this contact causes the roll and shaft

to revolve around their own axis in an opposite direction. These mills are best adapted to belting, and may be driven from a vertical motor, or a horizontal motor with a quarter-turn belt. The Griffin mill is manufactured by the Bradley Pulverizer Co., Boston, Mass.,

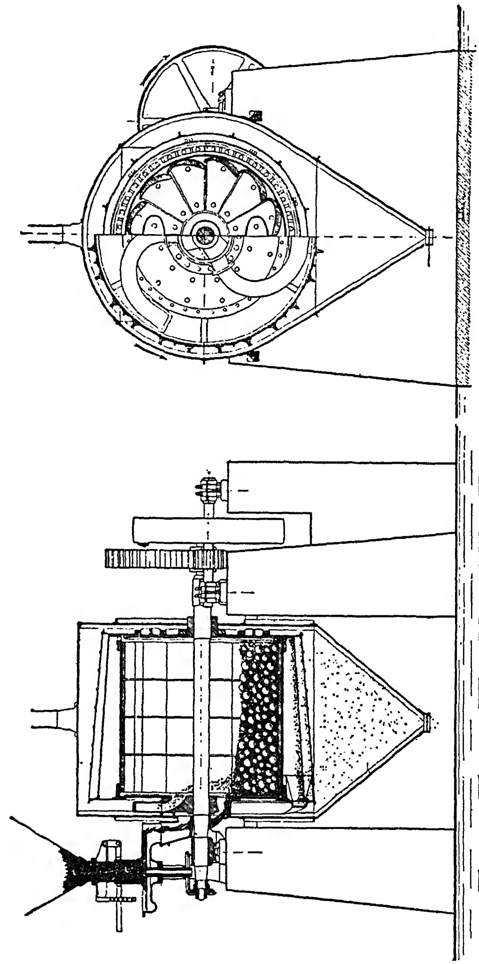


Fig. 134. Kominuter.

in two sizes, 30-inch and 36-inch, designated according to the diameter of the ring against which the crushing roll revolves. A new mill has been brought out by this firm, called a Three-Roll Griffin Mill. This is similar in its action to the standard mill, but, as the name implies, has three crushing rolls instead of one.

Fuller Lehigh Mills. These are called Fuller mills. They are used on the same material as the Griffin mill, described above, and

the grinding is done by four unattached chilled-iron balls, about 9 inches in diameter, that are propelled by four equidistant horizontal arms or pushers radiating from a vertical central shaft. The orbit is a circular die, against which the balls exert great pressure, since they weigh about 112 pounds each and revolve at about 210 r.p.m. The main shaft is driven from a pulley mounted at the bottom below the grinding level. This mill, which is shown in Fig. 136, is built by the Lehigh Car Wheel and Axle Works, Catasauqua, Pa.

Kent Pulverizer. The Kent pulverizer, which is also widely used

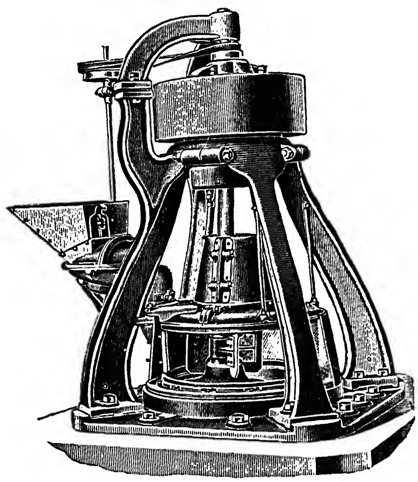


FIG. 135. GRIFFIN MILL.

for coarse and fine grinding, is illustrated in Fig. 137 in a sectional view. The ring revolves and the three rolls press against its inner face. These are the only four wearing parts. The rolls are convex and the ring is concave and tracks are provided on the rolls. The springs support the rolls yieldingly and the rolls support the ring, so that the four crushing parts are free to move to pass iron or uncrushable objects and are cushioned to take up shock and vibration and prevent crystallization or breakage. The rock falls from the inlets to the inner face of the ring. Centrifugal force holds it there in a layer an inch deep. It revolves with the ring, and passes under the rolls. The rolls are pressed by the springs outwardly against the rock on the ring with a pressure adjustable to 20,000 lbs. by the screws against the springs. The rolls roll over the rock, crushing it against the ring. The crushed rock flows off each side

of the ring into the casing and falls to the discharge. The body of the rock between the rolls and the ring makes 90 per cent. of the rock abrade on itself in crushing, thus reducing the wear on the

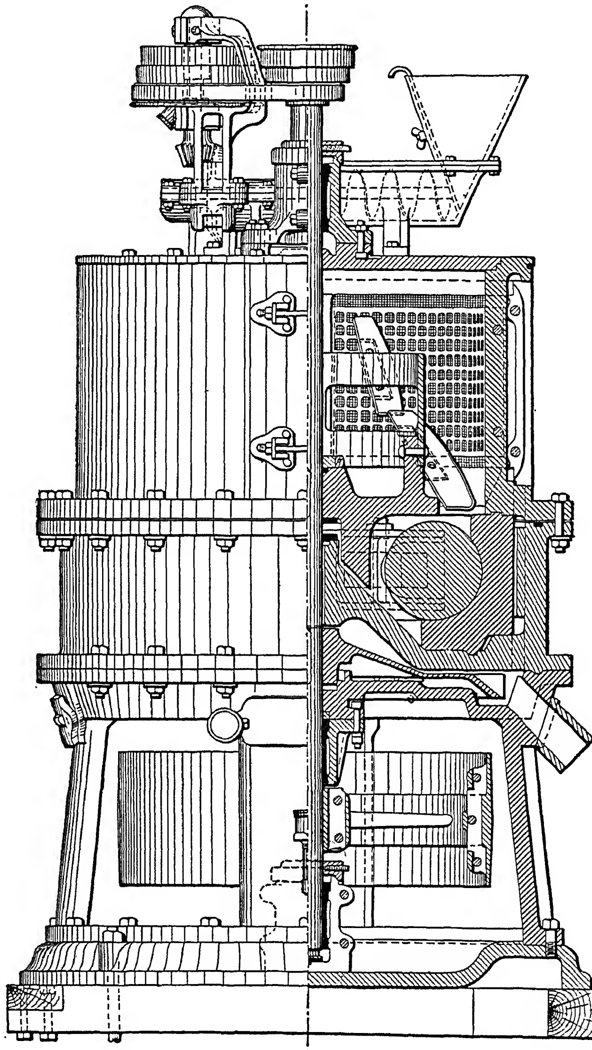


FIG. 136. FULLER MILL.

wearing parts. This mill is built by the Kent Mill Co., New York.

Raymond Mills. A mill which is widely used in the industries on account of the convenient accessibility to its inner parts is built

by the Raymond Brothers Impact Pulverizer Company of Chicago, Ill.; for grinding finer than to 100-mesh air separators are attached to this mill, as illustrated in Fig. 138.

Aero Pulverizer. For pulverizing coal and for transporting the coal dust mixed with the amount of air necessary for combustion to a kiln or furnace the so called aero pulverizer shown in Fig. 139 is successfully used. This machine consists of three interiorly communicating chambers of successively increased diameter, in which revolve paddles on arms with correspondingly increased radii. These three chambers are in fact three separate pulverizers on a single

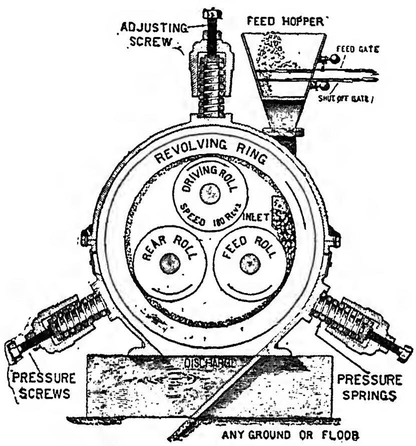


FIG. 137. KENT PULVERIZER.

axis, each succeeding pulverizer having longer arms and therefore greater speed at the periphery, and greater power for fine pulverization. The fourth chamber contains a fan whose function it is to draw the more finely pulverized material successively from one chamber to the other and finally to deliver it through a pipe connection to the furnace on the impetus of a forced draft. The three pulverizers and fan are enclosed in one steel cylinder. A regulable feed device accurately controls, and by moving a lever varies the quantity of coal admitted to and delivered by the machine. Two regulable inlets in the feed device admit the air required for pulverizing purposes. An auxiliary inlet between the third work chamber and the fan is controlled by a damper and admits such additional air as is required to bring the total air supply up to the theoretical requirement. The auxiliary air is intimately mixed with the pul-

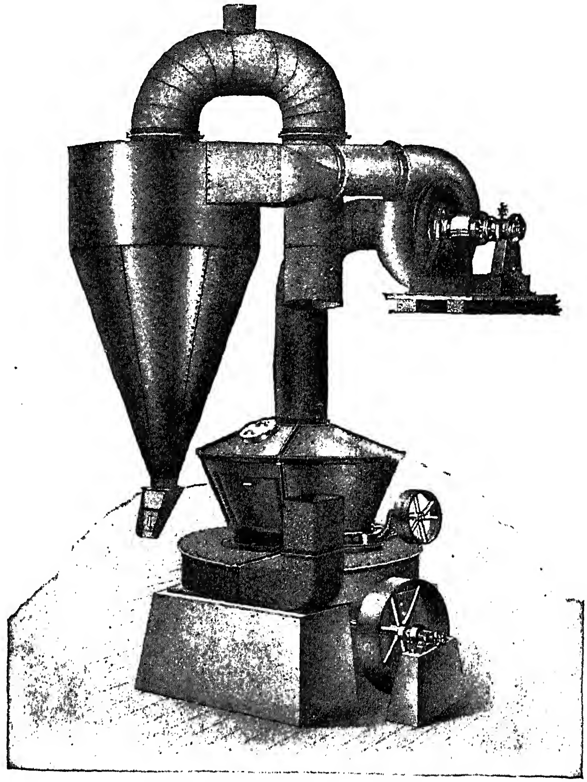


FIG. 138. RAYMOND MILL.

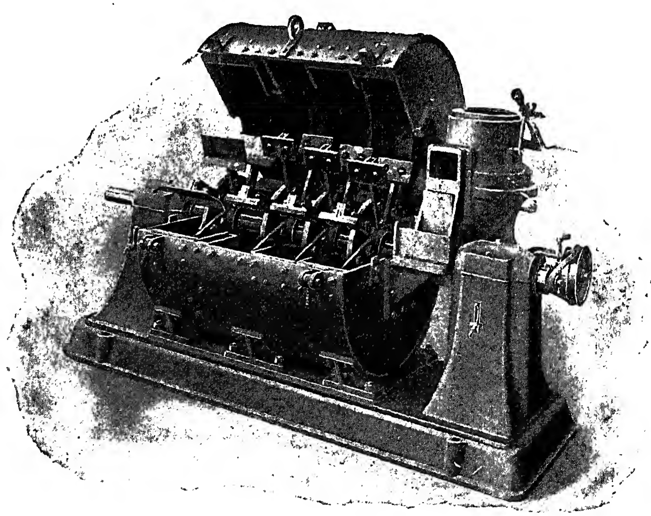


FIG. 139. AERO PULVERIZER.

verized coal in the fan chamber. These machines are built by the Aero Pulverizer Co. of New York.

Coal and Coke Crushers. The use of bituminous coal and appliances for spouting to boilers and stoking necessarily called for devices to reduce the lumps to a proper size.

Fig. 140. The Link-Belt standard two-roll crusher. It will reduce run-of-mine bituminous to $2\frac{1}{2}''$ and under.

With the Link-Belt fluted two-roll crusher for fine crushing, the

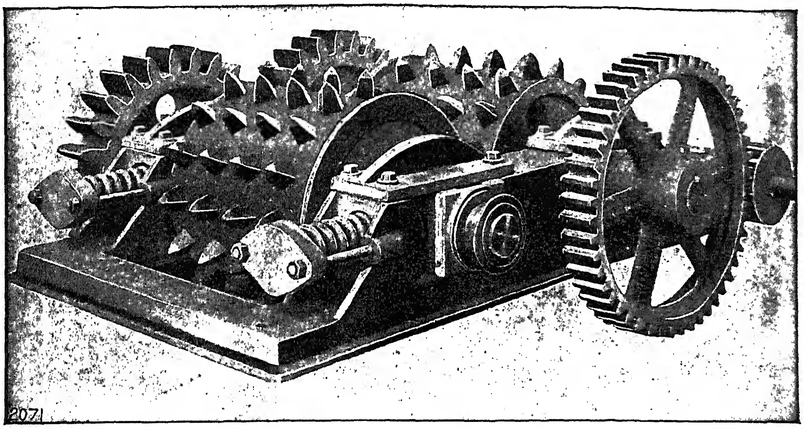


FIG. 140. 2-ROLL CRUSHER.

rolls are geared to run at differential speeds, so as to produce a tearing action on the lumps; it reduces oven coke to domestic size.

The Link-Belt disintegrator is employed for very fine crushing of coal as required in cement works and in by-product coke oven plants. Used in adddition to a crusher so that run-of-mine coal can be reduced to $\frac{1}{2}''$ and under. For the best results, either stationary or power screens should be placed between crusher and disintegrator.

CHAPTER IX.

MIXING MACHINES.

The kind of mixing machines to be used in a manufacturing process depends upon the thoroughness of the mixture required. It is evident that with an unequal mixture of two materials supposed to undergo a chemical reaction with each other, at one point the one substance, at another point the other will be in excess, causing a lack of uniformity in the process. Before the materials are mixed their correct weight has to be determined.

Scales. Fig. 141 represents an automatic scale for pulverized material with feeding device and sifter attached, as built by Werner and Pfleiderer, Saginaw, Mich. The operation is very simple: after the correct weight has been set on the scale beam, the starting rod is pulled. The feeder operates until the desired amount has been deposited in the scales, then stops automatically. These scales are also supplied without sifter.

An automatic scale for water and other liquids, built by the same firm, is shown in Fig. 142.

Mixers. The mixing appliances are classified as follows: Mixers for (1) solids, (2) solids and liquids, (3) liquids, (4) liquids and gases, and (5) gases.

The best and at the same time simplest mixing machines for dry and wet solids are built by Werner and Pfleiderer, Saginaw, Mich. On account of the rapidity of operation and thoroughness of mixture obtained, these machines are used quite extensively.

In selecting the proper size of these machines the most difficult mixing process can be performed in the most successful manner. It is to be mentioned that these machines are used not only for mixing dry, but also wet materials, in which case they also act as kneading machines. The special features of these mixers and kneaders are as follows:

1. The peculiar kneading blades (mixing and kneading arms), which possess different forms according to requirements, and which revolve in two hollow semi-cylinders, intersecting in each revolution successively every point on the surface of the surrounding cylinder,

so that no particle of the material can escape getting into the action of the blades.

2. The reversing apparatus, by which the blades are made to revolve either backwards or forwards, whereby the process of mixing

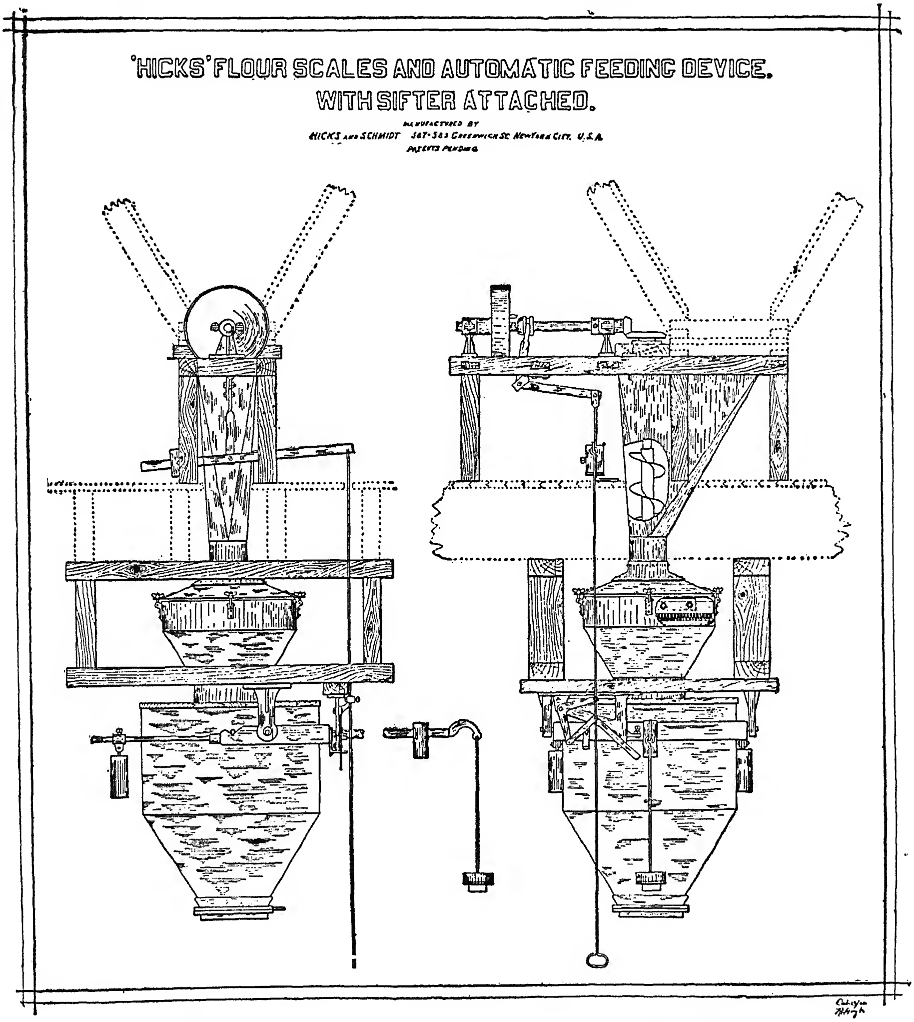


FIG. 141. AUTOMATIC SCALE FOR PULVERIZED MATERIAL.

and kneading is accelerated and the discharge of the material greatly facilitated.

3. The troughs of the machines, which are shaped according to the requirements of the material to be treated and which are mounted

so low that all materials can be charged and discharged conveniently.

These kneading and mixing machines are of very solid construction and usually built in iron and steel. For materials, however, which should not be brought in contact with iron or where the

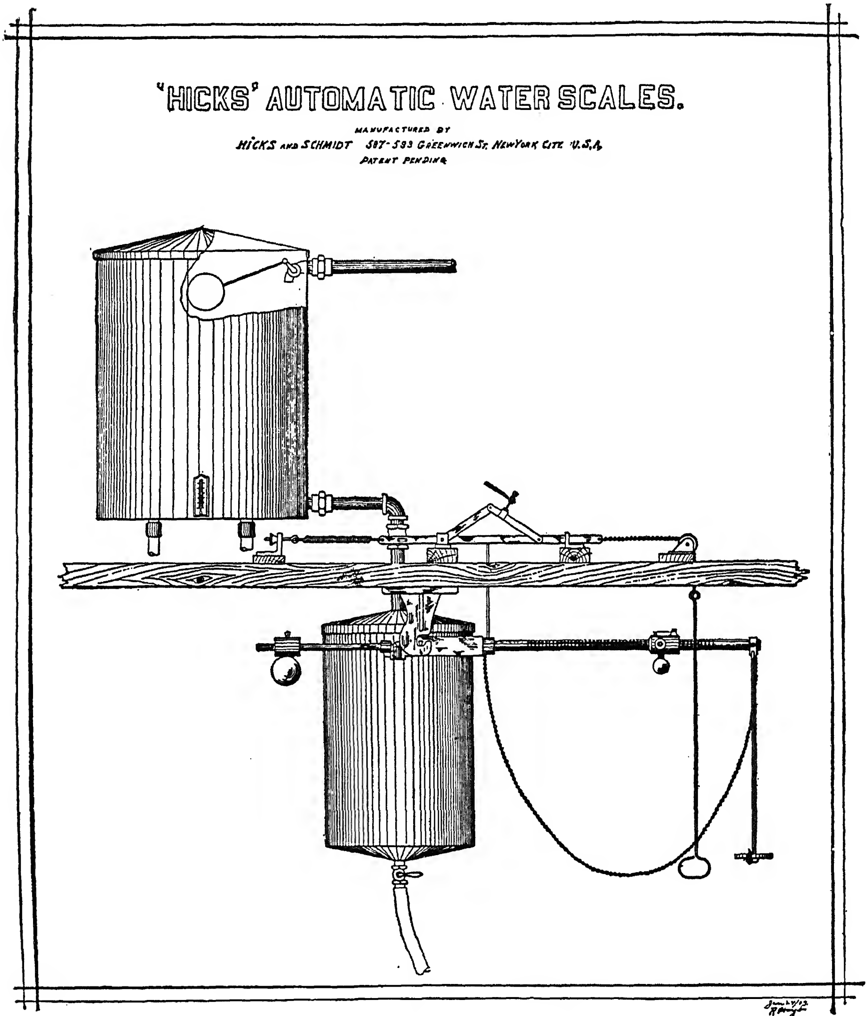


FIG. 142. AUTOMATIC SCALE FOR LIQUIDS.

machines must be protected from the effect of acids, etc., the trough and blades of the machines can be galvanized, made of bronze or any other suitable material, and where iron must not work against iron the blades are made in brass. In cases where the materials to be

treated produce a severe wearing effect upon the trough and blades, the trough is fitted with a movable lining and specially protected blades are provided.

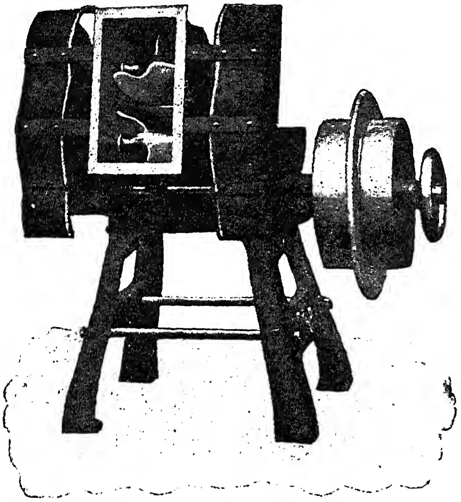


FIG. 143. MIXING AND KNEADING MACHINE.

The blades may be constructed hollow and the trough jacketed to permit heating by steam or cooling by cold water. Such arrangements are applied where materials (gutta-percha, chewing gum,

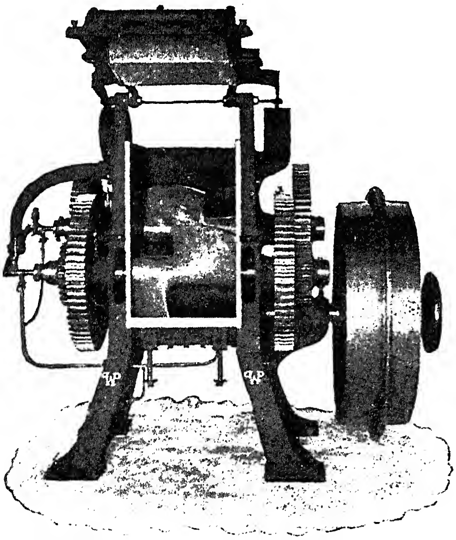


FIG. 144. MASTICATOR.

chocolate, licorice, etc.) require heating to facilitate the process of mixing and masticating, or where cooling of the material is considered necessary or desirable.

These machines are constructed with slow as well as fast speed

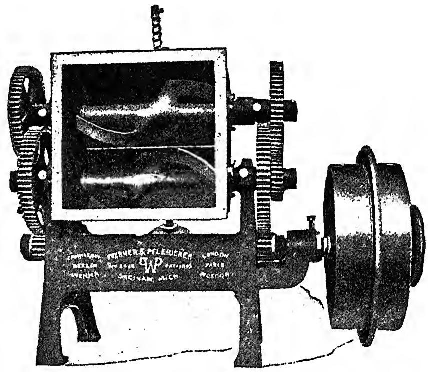


FIG. 145. MIXER FOR HAND TILTING.

and also with an arrangement for two speeds so as to suit the numerous requirements of various industries. They are built in three strengths: Class BS (gears on one side) are strong machines

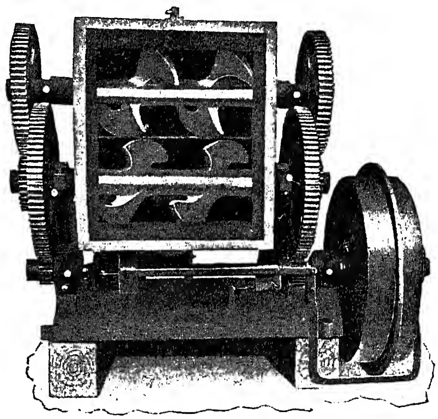


FIG. 146. MIXER WITH POWER TILTING ARRANGEMENT.

for kneading and mixing every description of rubber cements, crucible paste, ointments, oils and powders.

Class BB (gears on both sides of trough) are adapted for the manufacture of pill masses, red and white lead, stiff putty, smokeless gunpowder, etc.

Class BBB and C, the very strongest and heaviest built machines, are employed for very tough masses and where occasionally extra-

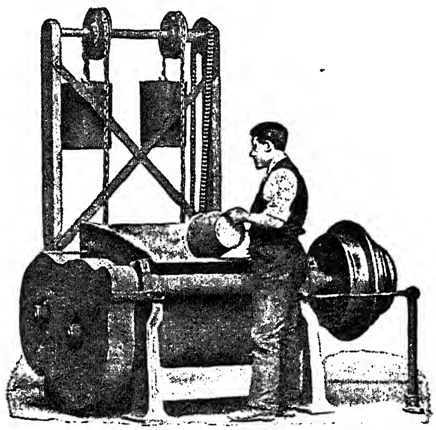


FIG. 147. MIXER WITH LOW TROUGH.

ordinary sudden jerks and resistance are encountered as with gutta percha, india rubber, linoleum, celluloid, etc.

In the machines shown in Fig. 143 the trough can be taken apart with great ease, hence the trough and working parts can be cleaned

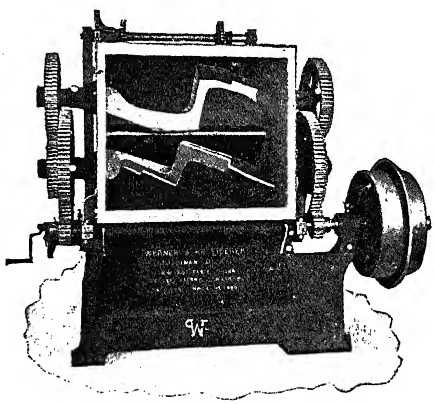


FIG. 148. PAPER PULPING MACHINE.

and washed as scrupulously and perfectly as may be desired. For discharging contents it can be tilted as shown in the cut.

The type "Masticator" shown in Fig. 144 is a special construction for the kneading, masticating and malaxating of very tough masses. The trough and blades are constructed for heating by steam; only

two connections have to be made, one for steam inlet and the other for the waste steam. For cooling purposes cold water may be turned on same fittings instead of steam. In view of the great resistance to be overcome in treating very stiff materials, these mas-

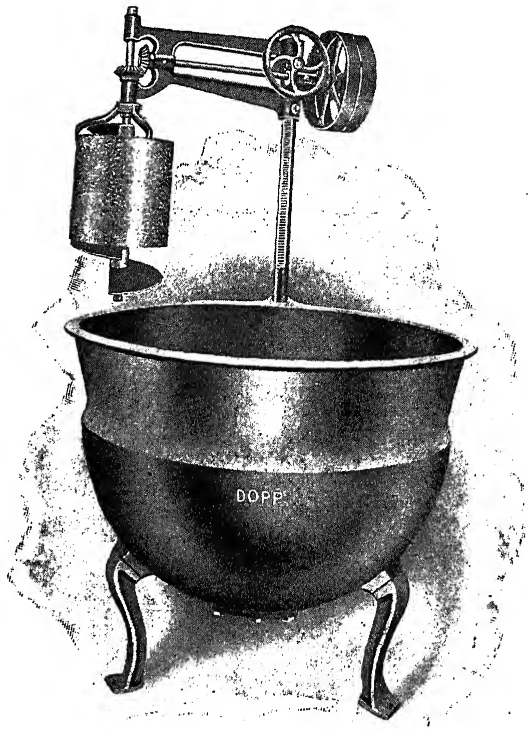


FIG. 149. AGITATOR, STYLE A.

ticators are very strongly built. The discharging of the material is effected by raising a flap door in front of machine.

Figs. 145 and 146 are very rigid, all around useful types. Fig. 145 is tilted by hand by means of a crank. Fig. 146 has power tilting arrangement, which is set in action by a foot or hand lever. Fig. 145 can be fitted with special arrangement for mixing at fast and medium speeds materials, the consistency of which changes during the treatment. These types are built with a capacity from 20 to 150 gallons.

The distinctive feature of the machine shown in Fig. 147 is that the trough hangs very low in its frame, thereby rendering the charg-

ing and discharging of the machine more easy and convenient than with any of the other types. There are no steps needed and the attendant does not have to stoop to get access to the working parts inside the trough. The machine illustrated has hand tilting gear, aided by counterweights, which makes the tilting arrangement by hand very easy and convenient. This machine, which is built in

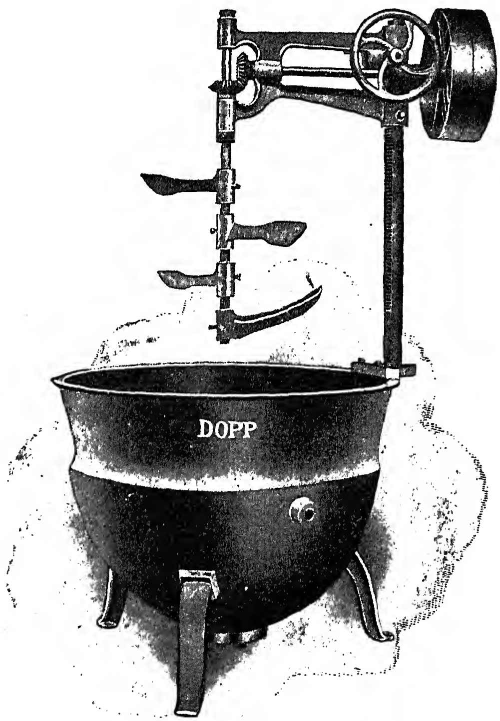


FIG. 150. AGITATOR, STYLE B.

sizes ranging from a capacity of 20 to 290 gallons is also built with power tilting arrangement, which is set in action by a foot or hand lever.

Fig. 148 illustrates the Universal Paper Pulping Machine built by the same concern. This machine consists of a trough with two hollow semi-cylinders in which revolve two agitators. These agitators intersect in each revolution successively every part of the surface of the surrounding cylinder so that no particle of the paper stock can escape getting into the action of the agitators, which tear it up and pulp it as thoroughly as may be desired.

This machine disintegrates all kinds of paper. It preserves and separates the fiber without breaking it and produces a pulp which can be made into very strong and highly finished paper.

Mixing of Liquids, Fats, Lumpy Materials, etc. For mixing light and heavy liquids, etc., preferably kettles are used which are provided with agitators. A great variety of these agitators is built by H. W. Dopp Company, Buffalo, N. Y. The agitators are fur-

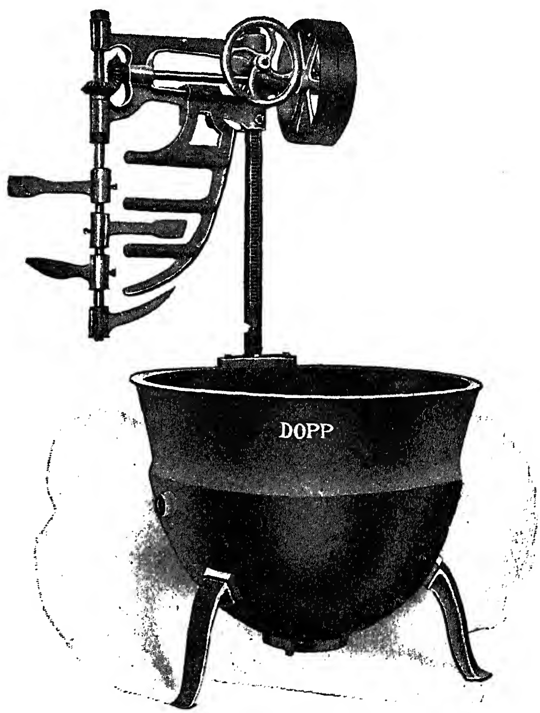


FIG. 151. AGITATOR, STYLE C.

nished driven by hand, belt, steam, electric power and by bevel gears and clutch direct from overhead shaft.

In the machines built by this firm the agitators can be raised and lowered at will, which greatly facilitates removing of the contents or cleaning of the kettle. The machine shown in Fig. 149 is extensively used in the soap industry on account of the rapidity with which the kettle can be cleaned and cooled. The agitator shown in Fig. 150 is especially adapted for mixing and agitating light materials, where it is desired to assist evaporation by agitation, or to

keep a substance agitated to prevent burning. The construction illustrated in Fig. 151 is used for mixing light but lumpy materials and is provided with an additional sweep arm, which has a tendency to break up the substances being mixed. Fig. 152 shows a double motion mixer (bracket type): the outside sweep with attached arms

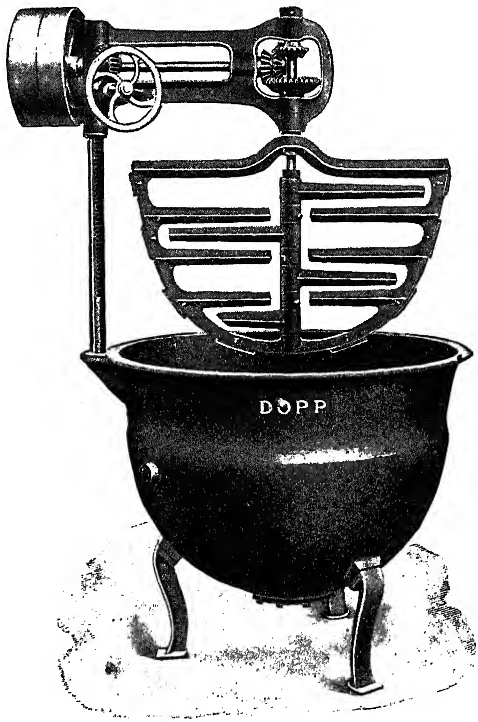


FIG. 152. AGITATOR, STYLE D, BRACKET TYPE.

revolves in one direction, while the center shaft and arms revolve in the opposite direction and at twice the speed. For mixing heavy materials the double motion agitator, shown in Fig. 153, is used. In this construction the bridge type of drive is applied to obtain the additional strength necessary to mix heavy material in batches of 100 to 500 gallons.

The description of the cast-iron, seamless, steam-jacketed kettles, which are used in connection with these agitators, is contained in Chapter XIII.

Mixing of Gases and Liquids. A very convenient apparatus for performing this operation and for stirring liquids by means of air

is the steam jet blower manufactured by the Schutte and Koerting Co. The action of the steam jet agitator is based upon the fact that a steam jet issuing from a small nozzle into a larger carries along the surrounding air and gives this air a velocity sufficient to overcome a pressure of fully eight feet of water. The air escaping with great force from the holes in the pipe fixed at the bottom of the tank, causes a violent agitation of the liquid surrounding it and

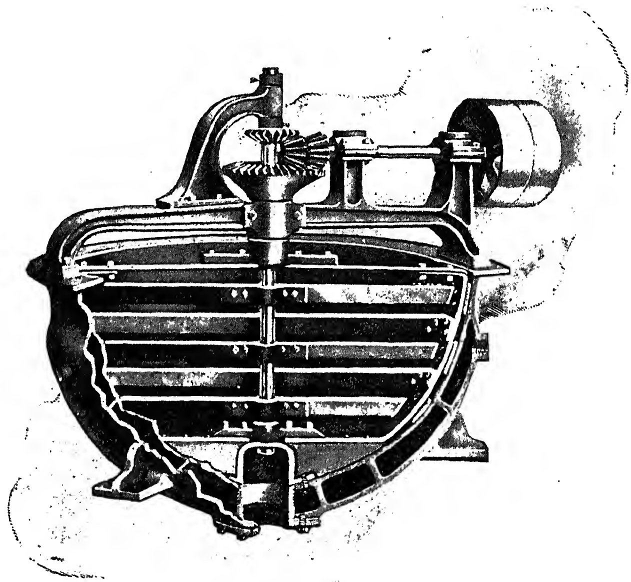


FIG. 153. DOPP'S AGITATOR, STYLE D, BRIDGE TYPE.

stirs up and drives in all directions any solid matter or precipitates resting at the bottom. Compared with air pumps, these apparatuses have advantages that give them preference wherever applicable.

The agitator is best placed so that its head stands above the highest level of liquid. The distributing air pipes have two rows of holes equally distributed and pointed downward. The number of these holes are fixed by the rule that the combined area should equal twice the area of the air pipe of the agitator. The diameter of holes should not exceed $\frac{3}{8}$ inch.

The agitating arrangement is especially useful in chemical works, where the operation of stirring is frequently of importance. Fig. 154 shows the application of such an agitator. In this case the

pipes are made of lead and rest on lead supports to give clearance between pipes and bottom of the tank, so that the air can blow against the bottom of the tank and keep the solution in circulation.

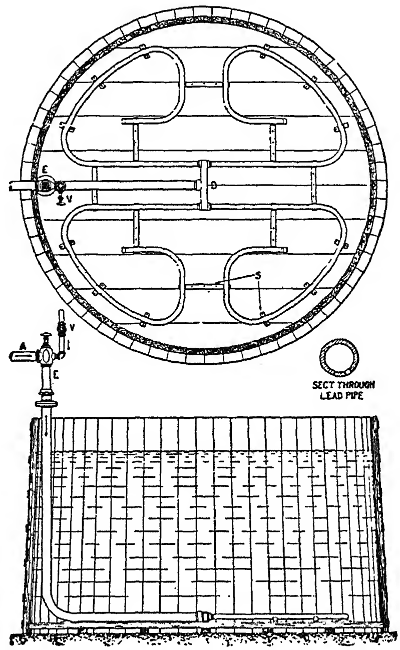


FIG. 154. APPLICATION OF STEAM JET AGITATOR.

Another example for the mixing of gases and liquids is the production of sulphuric acid, as shown in Fig. 155. *A* is the absorp-

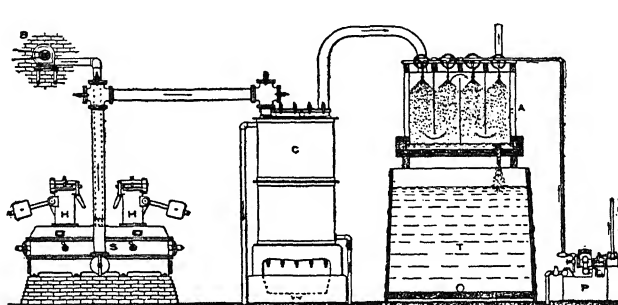


FIG. 155. SULPHUROUS ACID PLANT.

tion chamber with spray nozzles; *B* the blower for air supply; *C* the cooler; *H* the hopper; *P* the pumping outfit; *S* the sulphur fur-

nace; *T* the storage tank. In this apparatus the blower forces the combustion air to the furnace, the sulphurous acid gases pass through the cooler to the absorption chamber, where the gas is absorbed by the atomized water; the water pressure is created by a pumping outfit, if there is not already pressure water at disposal. The absorption chamber is so arranged that the gases have to pass up and down, being on their way absorbed by the atomized water.

CHAPTER X.

FIRING AND FURNACES.

Producer Gas Firing. In the last ten years great strides have been made in the application of producer gas for fuel purposes, and it has been found that the use of this gas in place of direct firing with coal presents the following advantages:

1. While with direct firing it is impossible to get a complete combustion, this result can be easily obtained by using producer gas.

2. Even with the lowest grades of bituminous fuels a practically smokeless combustion is obtained by transforming such fuels into producer gas.

3. With gas firing the temperature is easily regulated and kept constant.

4. With producer firing the waste heat of the products of combustion can be utilized for preheating the combustion air or the gas, whereby a considerable saving in fuel is effected.

5. With producer gas firing a slight excess of either air or gas can be used, if so desired, for obtaining an oxidizing or reducing flame, which is of special importance to the chemical industries.

6. With producer gas firing the material to be heated does not come in contact with the solid fuel or ashes. Thence, for instance, in using gas in a lime kiln a purer product will be obtained than with direct firing. In using producer gas under a boiler the life of the latter will be prolonged on account of the purity and uniformity of the flame.

7. Less skill is required for taking care of a gas-fired installation than of a direct fire.

8. Producer gas firing is especially adapted for central stations, as the gas produced in one producer or in a battery of producers can be distributed through pipes to a large number of furnaces.

The advantage of gas firing over direct firing is obvious, and can be easily understood from Fig. 156. The top view shows an ordinary direct fireplace for coal, to which the fuel is charged through a side door. The latter fact makes it difficult to keep up a fuel bed of uniform thickness all over the grate. The bottom

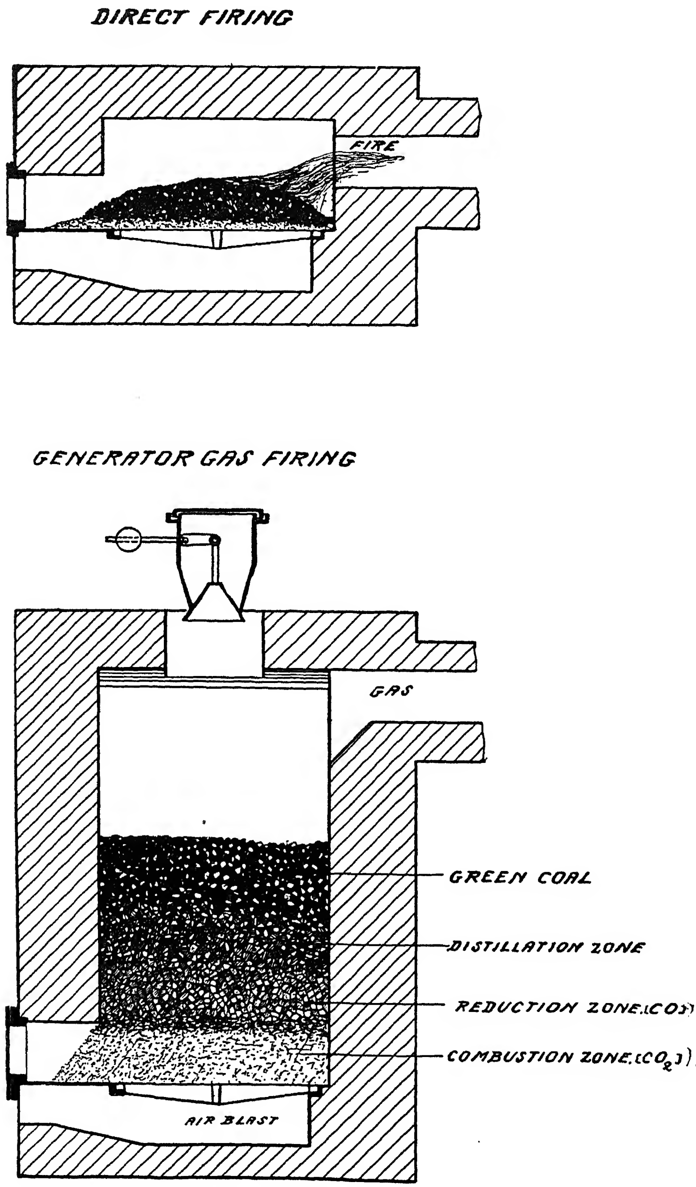


FIG. 156. COMPARISON OF DIRECT FIRE PLACE WITH GAS PRODUCER.

view shows a gas producer into which the coal is fed from the top by gravity, which is undoubtedly a more rational and convenient way, whereby at the same time a fuel bed of uniform thickness can be maintained without difficulty.

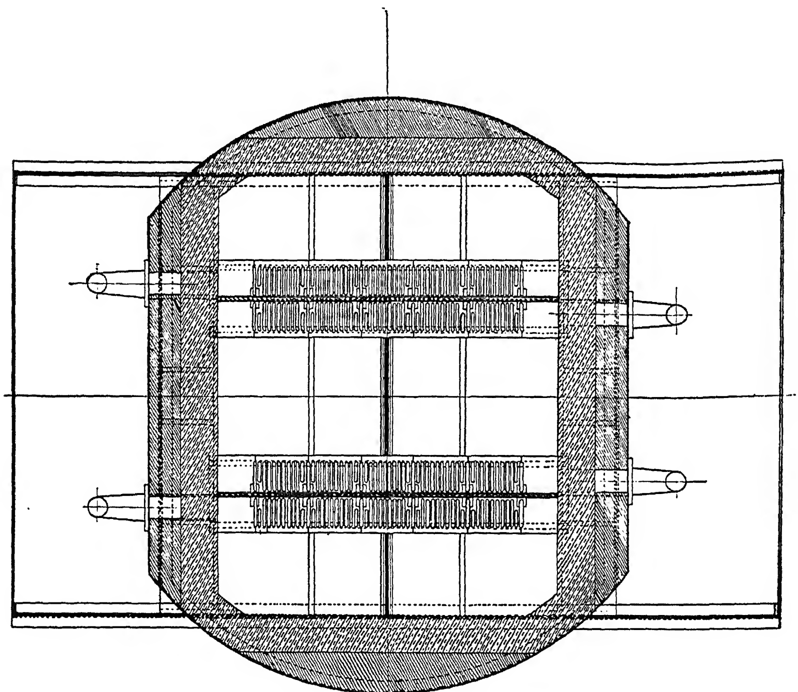
A comparison of these two illustrations further shows that there is nothing complicated in a gas producer and that the same can be defined as a grate fire carrying a fuel bed of considerable thickness, say of three feet. It does not matter whether the grate is formed by bars or ashes.

The manufacture of producer gas consists mainly in drawing by means of natural draft or a fan, or by blowing by means of a blower, air through a fuel bed of certain thickness. The entering air combines with the carbon of the bottom layer to carbon dioxide (carbonic acid), which is a gaseous, non-combustible product of complete combustion identical with the gas escaping from our chimneys. This gas, by going through the upper layers of the fuel bed, forms a chemical combination with the carbon of these layers and is reduced thereby, the result being the formation of carbon monoxide, which is a combustible gas, and is called producer gas. On account of the air blown through the fuel, this gas necessarily contains a certain amount of nitrogen.

The gas producer shown in Fig. 156 is a rather old design; the producers in use at present show many improved features, thence higher efficiency. It has been found that by blowing in place of air a mixture of steam and air through the fuel bed, a gas of much higher thermal value is obtained. It has been also found that the attendance necessary for running the producer is considerably reduced if, instead of supporting the fuel bed upon a grate, a so-called water seal is used, the fuel bed being supported by its ash. One of the most widely used producers of this style, the Bradley Water Seal Gas Producer, which is manufactured by the Duff Patents Co., Pittsburg, Pa., is shown in Figs. 157 to 160. Fig. 157 is a section showing top of grates and locations of steam jet blowers. Fig. 158 is a top view and Figs. 159 and 160 are sectional views. This producer, which is extensively used in chemical and metallurgical works, is very simple and efficient. The coal is completely burnt into white clean ash, which is simply shoveled out of the water-sealed bottom by unskilled labor. The operation is continuous, and as one man can attend to a number of producers, nearly automatic. The sensible heat of the ashes is utilized in the producer for the formation of steam and vapor, which rises through the fuel, softens the ash considerably, assists in preventing the formation of clinkers and enriches the gas by its decomposition into hydrogen and oxy-

gen, the latter combining with the carbon of the coal to carbon monoxide. Hence the vapor rising from the ash troughs decreases the quantity of steam required for blowing.

No air can escape from the blowers up the sides of this producer. The air is properly distributed through numerous slots covering a large area, which results in an even and uniform combustion of the



SECTION SHOWING TOP OF GRATES & LOCATION OF BLOWERS

FIG. 157. BRADLEY PRODUCER.

coal and the absence of holes in the fire. There is no loss of gas by leakage, the gas being completely sealed by the water seal.

The special feature of the Bradley producer, which makes this construction very desirable, is the use of four blowers and four grates. It is to be stated that, while only two grates are shown in the cut, a dividing plate is provided between each grate, which practically makes four independent grates. For instance, should the fire get too hot at either of the end walls running parallel with the grate, the blowers controlling those halves of the grates are

closed down partly or entirely, as the case may require. This applies also to the center halves of the grates, which are controlled and regulated in the same manner. Hence an absolute control of the condition of the fire is effected by the regulation of the steam and air blast. This design also prevents the formation of an uneven fuel bed, thereby reducing the poking of the fires to a mini-

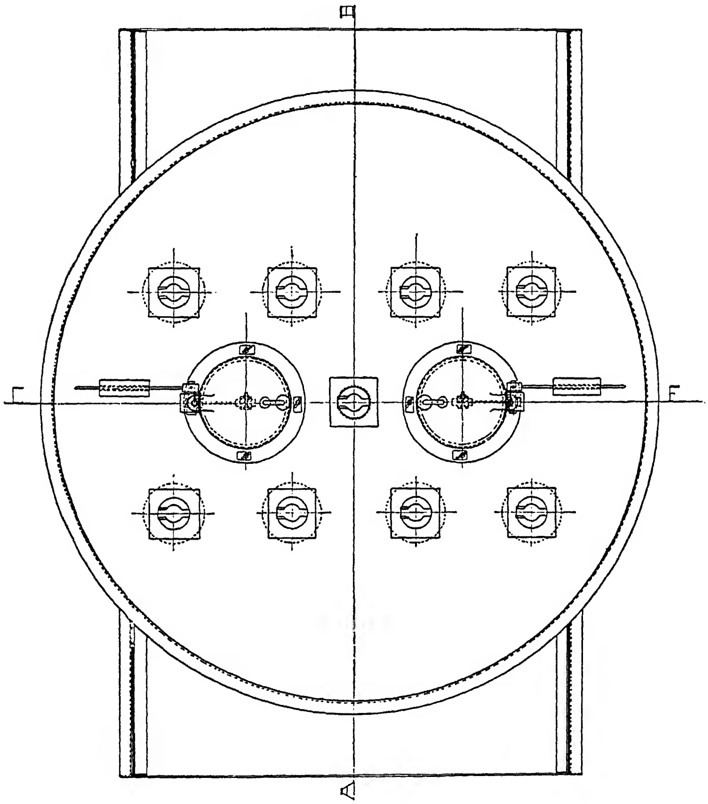
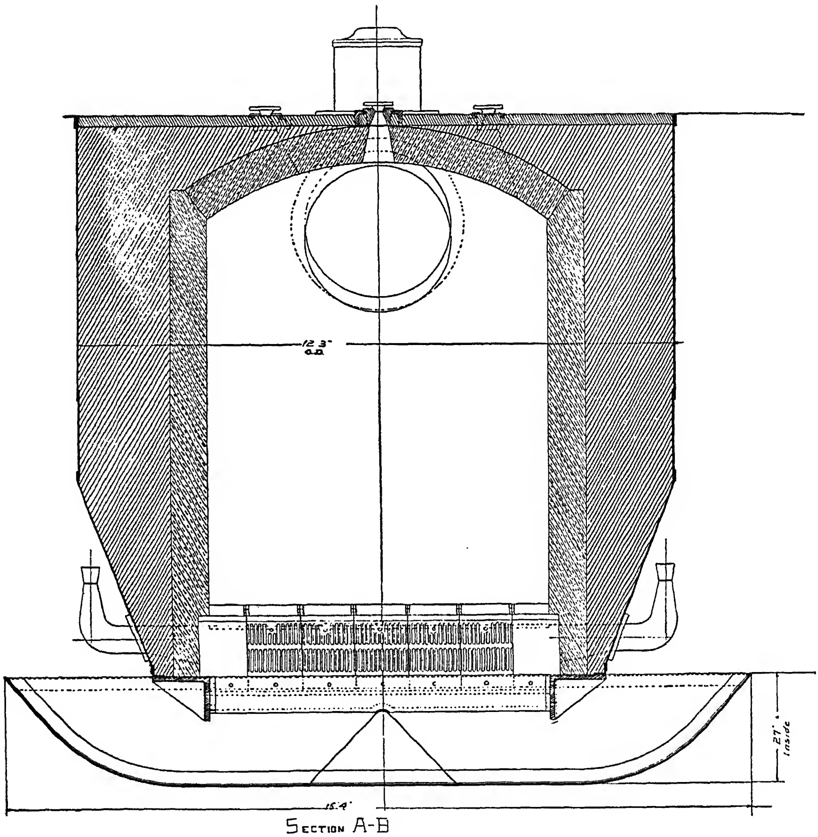


FIG. 158. BRADLEY PRODUCER.

mum, the result being a better and a more uniform quality of the gas.

Producer Gas-fired Boiler Plant. Fig. 161 shows a boiler installation provided with gas producer firing. It is easily understood that a battery of boilers can be heated by a battery of producers and that the boilers can be at any distance from the producers. In the plant shown in the illustration the producer gas goes at first to

the gas sewer *h*, which is connected by valves *v* with the gas distributing channels *a*, one of the latter being arranged below every combustion chamber *b*. Thence by closing a valve any boiler can be disconnected from the firing and the quantity of gas to be admitted to the boiler be regulated. Above the channel combustion chambers *b* are provided, into which the gas enters by a number



SECTION A-B

FIG. 159. BRADLEY PRODUCER.

of openings or tuyeres *d* from the channels *a*. In the combustion chambers *b* the gas is mixed with the air required for combustion. The latter enters through channels, goes through channels *l* (in the side walls of the combustion chamber) downward to the opening l^2l^2, through which it enters at both sides of the tuyeres *d* and is burned. Above the chambers *b* there are arranged chambers *c*, which are separated by an arch from the boiler tubes. Thence the

fire gases before touching the tubes have to pass two chambers, first the combustion chamber proper and then the upper combustion chamber, whereby a complete combustion of the gas is obtained. The arrangements of the channels *l* prevent a loss of heat by radiation.

Coal is charged into the producer every half hour, which is a

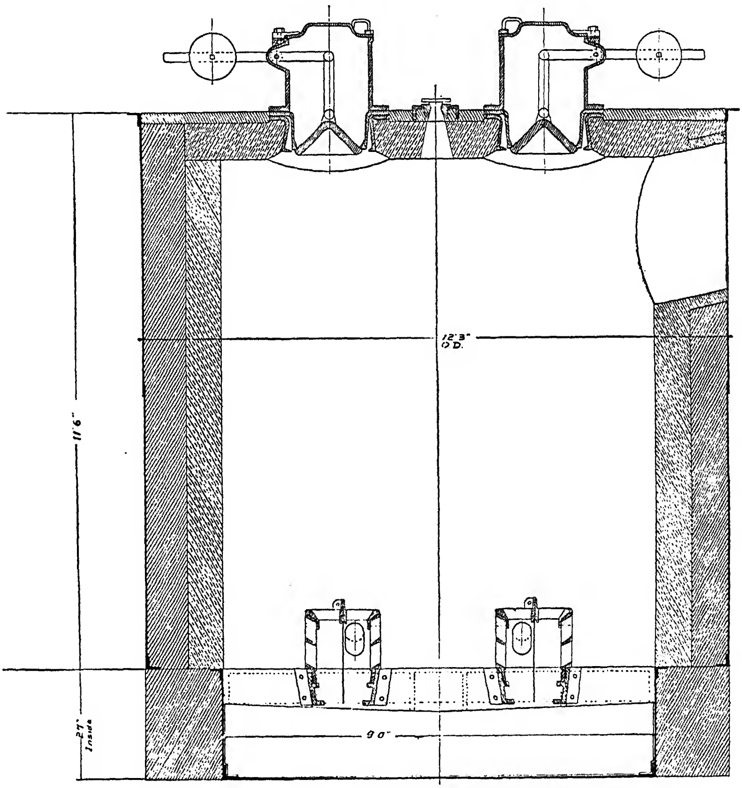


FIG. 160. BRADLEY PRODUCER.

simple operation; in fact, unskilled laborers are used everywhere for attending to producers, which means also a saving compared to direct firing, where skilled firemen have to be employed. Further advantages are the possibility of using low-grade fuel without interfering with smokeless combustion.

Producer Gas-fired Lime Kiln. An installation of this type is shown in Figs. 162 and 163. Being under pressure, the gas is

equally distributed over the entire area. The air arrives on account of the high temperature at the place of combustion under a certain pressure which prevents the drawing in of excess air and effects the uniform distribution of the air as well as of the gas. The combustion of the producer gas by the air is taking place between and above the gas inlets.

With such a producer gas installation a very uniform heat is

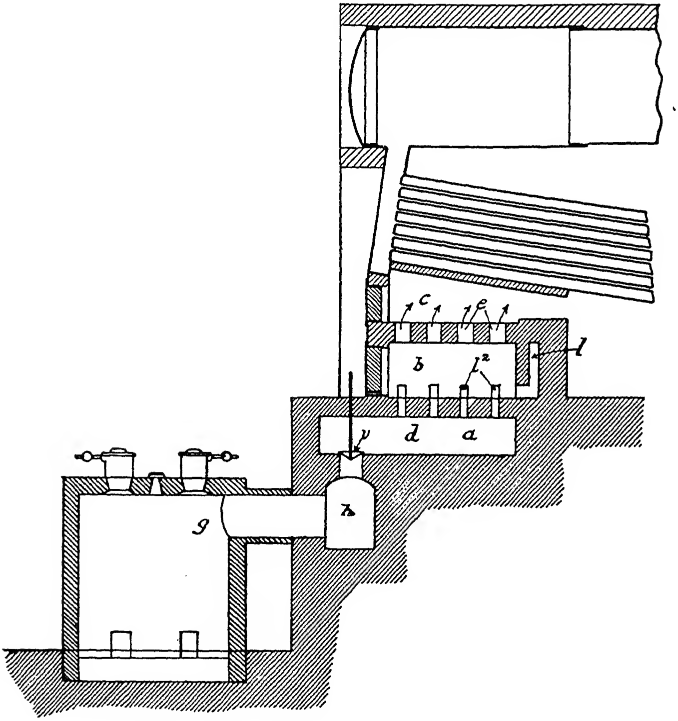


FIG. 161. PRODUCERGAS FIRED BOILER PLANT.

obtained, the utilization of the heat is far superior to direct fire, and a great saving in the fuel consumption is effected. Further advantages are the production of pure material and longer life of the shaft.

Producer Gas-fired Reverberatory Furnace. Reverberatory furnaces are widely used in the industries for melting, glowing, roasting and various chemical and metallurgical operations. Most of these furnaces, however, are at present still heated by direct firing, causing a great waste by fuel.

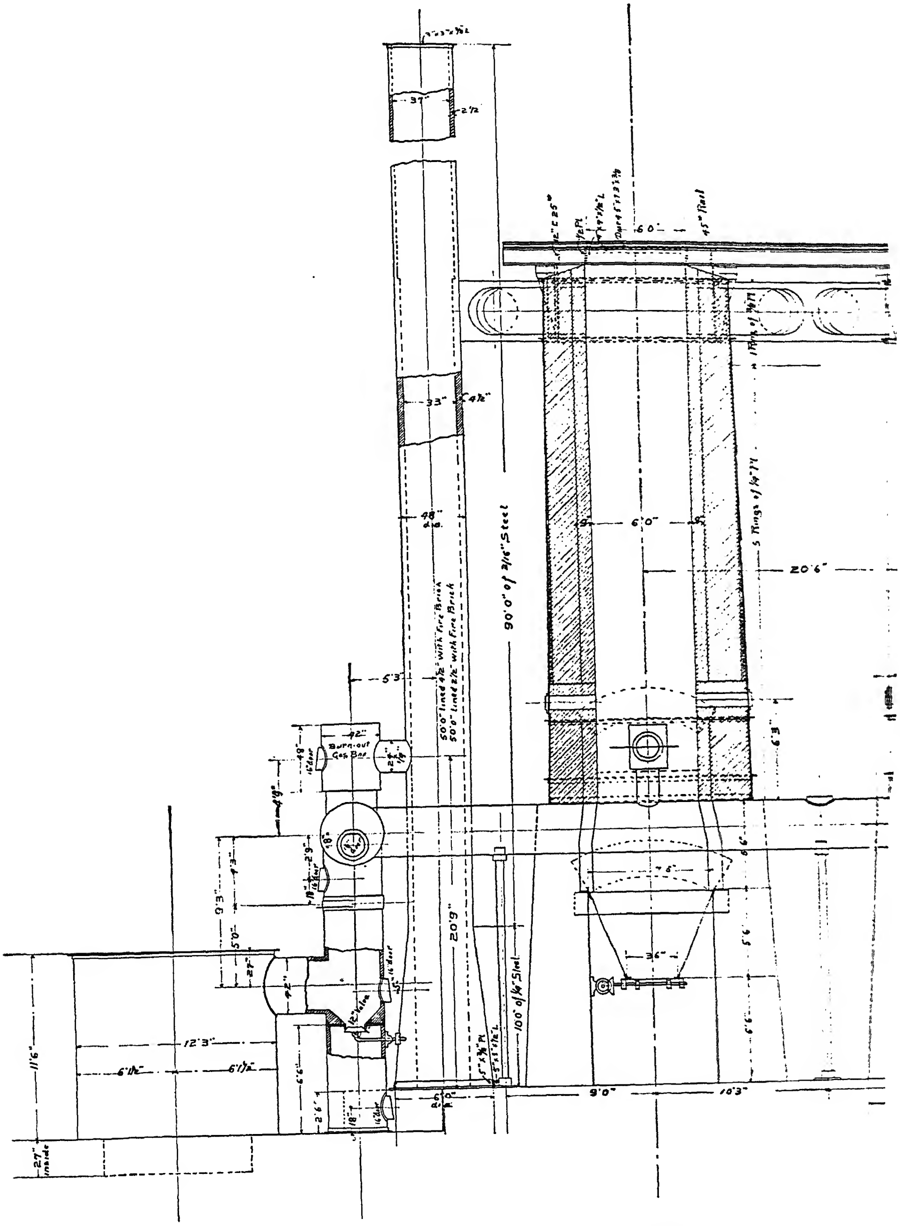


FIG. 162. PRODUCERGAS FIRED LIME KILN.

By providing such a furnace with producer gas firing, as shown in Fig. 164, a saving of 30 per cent. of fuel is effected. The change

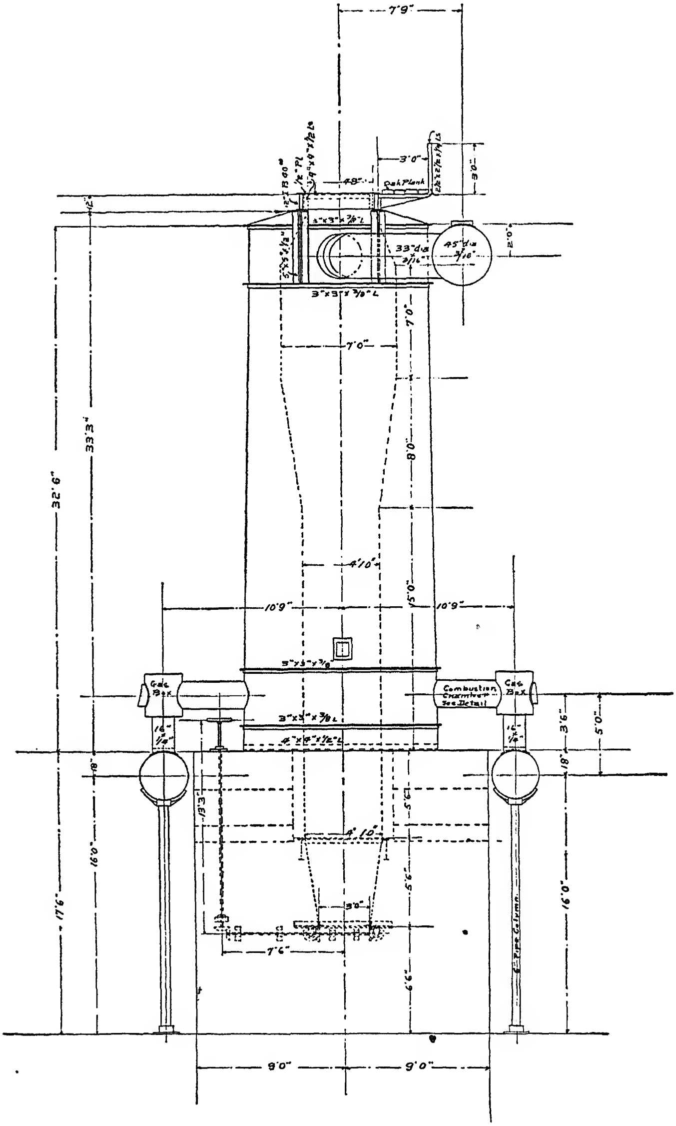


FIG. 163. PRODUCERGAS FIRED LIME KILN.

from direct fire to gas fire consists mainly in the addition of the gas producer and recuperator between furnace and chimney. The

recuperator consists mainly of a system of fire clay pipes e_1, which connect the flue b with the chimney E. This pipe system is built into a wider channel L, in which the air required for the combustion of the producer gas is introduced at l. The air goes in channel L around the pipe system as shown in the cut by arrows, absorbs the heat of the escaping fire gases and carries this heat back through the furnace to the channels and openings i. These channels are connected with the hot-air chamber L of the recuperator by air slits or air channels l'. In these air slits, which are arranged throughout the width of the furnace arch, the air is brought to a still higher temperature. Thence at the fire bridge incandescent producer gas is mixed with incandescent air, causing a perfect com-

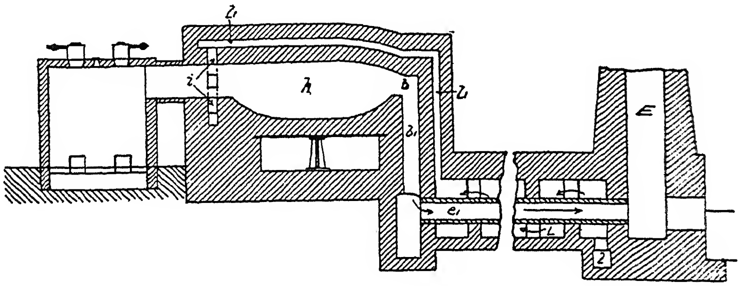


FIG. 164. PRODUCERGAS FIRED REVERBERATORY FURNACE.

bustion. In working with a reducing flame the combustion is nearly smokeless. It gets perfectly smokeless by the use of a slight excess of air.

The saving is effected by higher temperature obtained, by the recovery of the heat in the recuperator, by reducing the radiation of the fireplace, by the exact regulability of the firing, and the perfect combustion. The life of the fire brick work is considerably prolonged.

In installations where a temperature of 2000° F. to 3000° F. is required the gas and air have to be highly preheated before they are allowed to combine. This is effected by leading both the air and the gas through highly heated fire brick checker work contained in a chamber. There are generally provided two chambers for heating the air and two for heating the gas. While one of each chambers is used for heating, the other is heated by the waste heat of the products of combustion. So-called reversing valves are

used for alternately connecting the chambers with the gas and . supply pipe.

Producer Gas-fired Muffle Furnaces. In coal-fired muffle fı naces the combustion products escape at very high temperature af heating the muffle, which means a considerable loss of heat. Pı ducer gas firing is much more economical in such a furnace, as t waste heat can be used advantageously for preheating the combı tion air. Furthermore the sensible heat of the brick walls can a

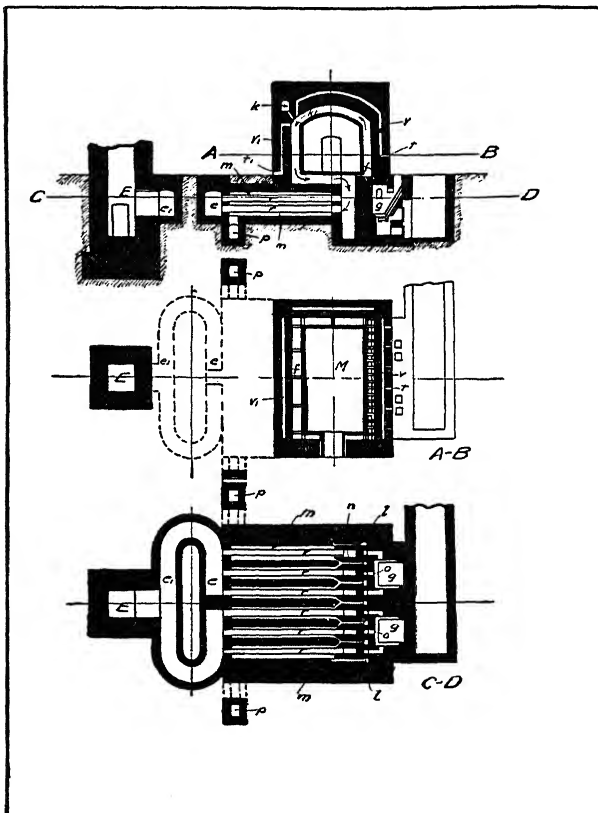


FIG. 165. PRODUCERGAS FIRED MUFFLE FURNACE.

be utilized for preheating air by providing suitable air slits. Fi 165 shows a producer gas-fired muffle furnace in vertical sectio horizontal section through the muffle proper, and a horizontal se tion through the recuperating apparatus.

The furnace shown in the cut is provided with two producer

The gas goes through openings O into the fire space f surrounding the muffle. At the entrance the gas is mixed with hot air, which is led to these points through channels l between the gas channels from the recuperator. The gas flame rises upwards, plays around the muffle arch and goes downwards, heating the bottom of the muffle. Then the products of combustion—still very hot—go through pipes r to the flues ee leading to the stack. The pipes r are built into wider channels m, into which air is led through channels p. This air plays around the pipes r opposite to the flame direction, and is heated by absorbing through the pipe walls the heat of the combustion products. The highly preheated air finally goes through channels n into pipes l, which lead to the fire space and are arranged between the gas pipes.

For effecting a uniform heating of the muffle, the producer gas can be led into the fire space also at a second and third place, and the sensible heat of the brick walls utilized for preheating the air necessary for oxidizing this quantity of gas. In the construction shown in Fig. 165, producer gas and preheated air is again allowed to enter at half the way of the fire gases around the muffle. The air necessary for burning this gas enters at t and t_1 through openings regulable by slides into the air slits v, v_1, arranged behind the fire-brick wall of the furnace. The producer gas entering at the second place is also taken from the producers.

The way of mixing the gas and the air is of fundamental importance for getting a complete and smokeless combustion. In a wide hearth the gas will advantageously be introduced in a number of parallel currents. In this case the air also has to be applied, so that there is one gas channel corresponding to every air channel. As the air is heavier than the gas, it is by no means immaterial whether the air channels are constructed above or below the gas channels. If the air is introduced above the gas a quicker combustion is obtained; reduction processes are conveniently performed with "upper air." If the air is introduced below the gas a slower combustion—*i. e.*, a larger flame—is obtained; oxidation processes are conveniently performed with "lower" air. While parallel currents of gas and air are to be used if a large area is to be heated, the gas and air are brought together under an angle for heating a narrow space; for heating a small object gas and air are combined at a right angle.

Producer Gas-fired Brick Kiln. Producer gas firing can be conveniently used in brick kilns and generally a direct-fired kiln can be transformed to gas firing at moderate cost.

The main advantage of the gas fire for this purpose is the fact that the heat of the burnt material can be utilized for preheating the combustion air. Furthermore low-grade fuel can be used, even if high temperatures have to be obtained or high-grade goods are to be burned.

With gas firing the material to be burned does not come in contact with ash, flue dust, etc.; thence fine goods which previously had to be burned in muffle furnaces can be burnt directly with gas.

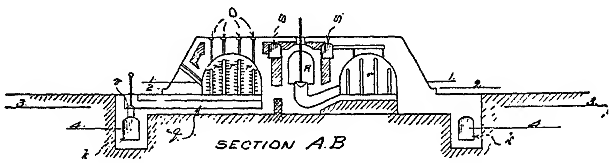


FIG. 166. PRODUCERGAS FIRED BRICK KILN, VERTICAL SECTION.

While with direct firing a number of fireplaces have to be operated, a saving in labor is effected with gas firing by the fact that only one producer plant has to be taken care of.

With gas firing an excess of air in the kiln or the admission of cold air is easily avoided.

It is evident that with only slight changes a coal-fired kiln can be adapted for gas firing. In place of the heating shafts (flues), vertical pipes (burners) closed on top, which are provided with rows of numerous gas-outlet openings or slits, have to be installed. These burners are connected by connecting flues or channels arranged in the sole of the kiln and by a main gas flue going all around the kiln, as shown in Fig. 166 (vertical section) and Fig. 167 (plan). The gas is fed from a gas producer to the flue *K*.

Below every firing hole there are built in vertically fire-brick tubes *R* closed on top, which end with their open bottoms into the cross-flues. By opening valve *v* these flues can be connected with the main flue *K*, so that whenever the valve is opened the gas will go to the connecting flue *q* and from here through the burner *R* into the burning kiln proper. The products of combustion are led through the flues *f* into the common flue *R*.

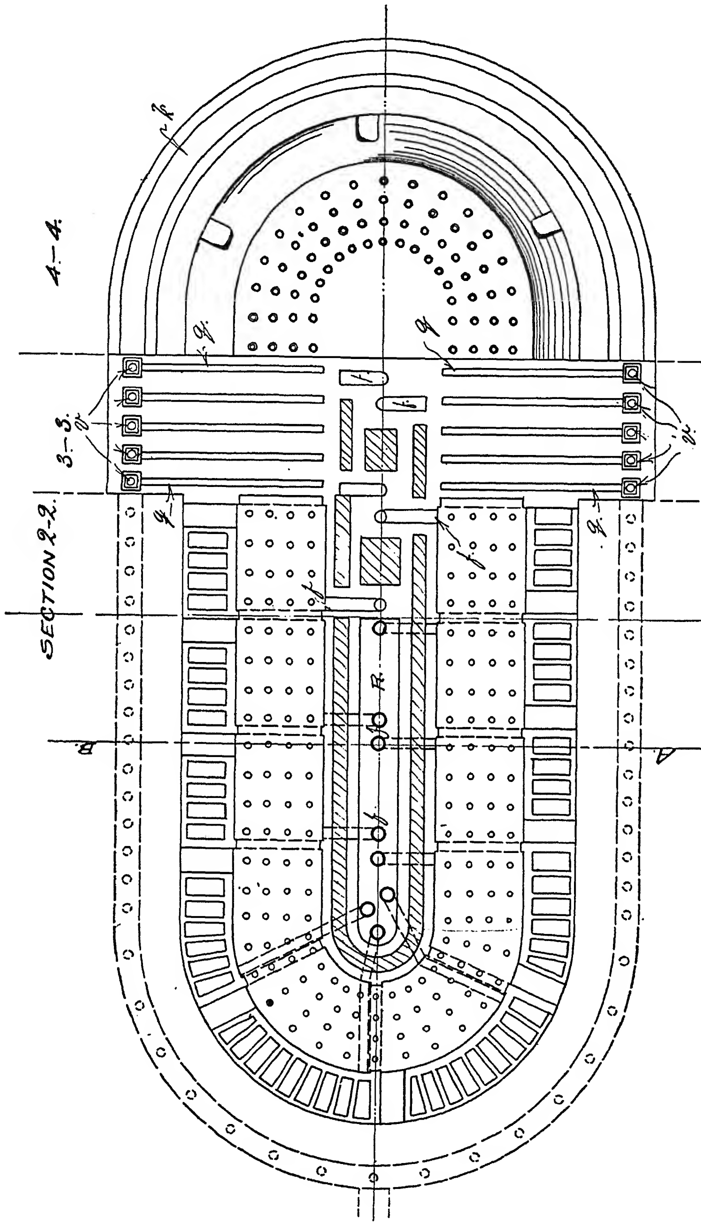


FIG. 167. PRODUCERGAS FIRED BRICK KILN, PLAN.

Through the flue S on top of the kiln hot air from a burnt-out chamber is conducted to a chamber charged with green goods.

As is seen from the above description, the air only is preheated

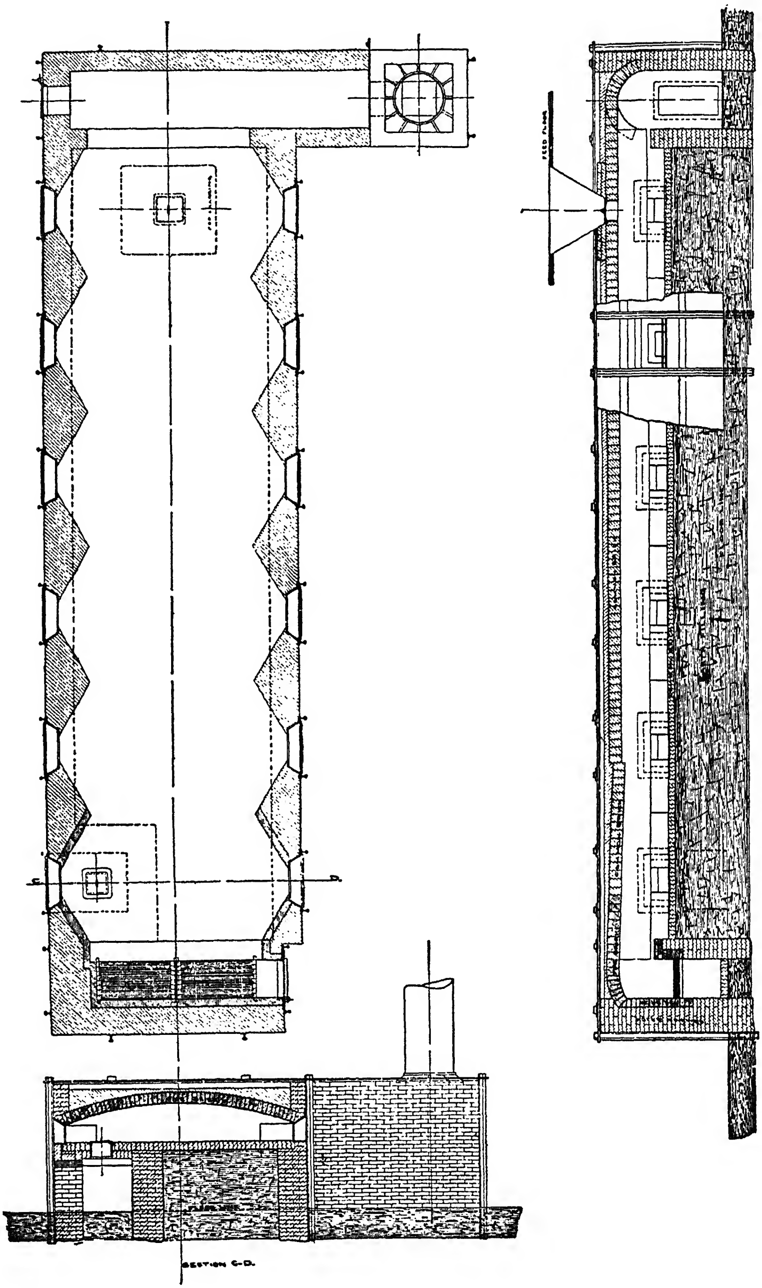


FIG. 168. HAND-STIRRED ROASTING FURNACE.

in this case, while the gas goes to the kiln without preheating. This necessitates the use of a fairly good grade of coal, while by preheating the gas also low grade of coal and even lignite, peat or wood can be used without difficulty for burning the most refractory materials. In Europe the system of regeneration (preheating gas and air in chambers filled with fire-brick checker work, which are heated by the product of combustion) is widely used and in one fire brick factory a saving in fuel of 40 per cent. and in time of 50 per cent. has been effected.

For the burning of goods which shall not come in contact with the fire gases, especially for burning fine enamels, muffle furnaces are used. In the heating of latter, producer gas presents many advantages as compared to direct firing. The waste heat of the products of combustion is lost with coal firing, while with gas firing it is used for preheating the combustion air. With gas firing the heat radiated by the furnace can be considerably reduced by arranging air slits behind the fire brick lining and leading the combustion air through same for the purpose of preheating.

Roasting Furnaces. Roasting furnaces may be classified under one of the following types: The hand-stirred reverberatory; the reverberatory with continuous discharge; the revolving cylinder with intermittent discharge; the revolving cylinder having continuous discharge; circular multiple hearth shaft furnaces; muffle furnaces.

With these furnaces wood, coal, gas or oil can be used as a fuel and all are intended for roasting crushed ore.

The ordinary hand-stirred reverberatory roasting furnace consists of a continuous hearth covered over with a low arch and having a fire-box at one end and a flue at the other. A furnace of this kind is illustrated in Fig. 168.

This furnace can often be economically built of stone up to the half level, the rest of the structure being constructed of brick, the entire mass being bound together with T-rails or I-beams. The hearth should be of sufficient area to suit the character of the ore and tonnage required. The Allis Chalmer Co. builds them in sizes ranging from 7 × 10 ft to 17 × 72 ft.

A good example for a reverberatory with continuous discharge is the Brown roasting furnace shown in Fig. 169. In its most improved form it is a single hearth reverberatory with an interior slotted wall on each side of the hearth, covered with a low arch.

This roaster is made straight or round in shape to suit local conditions. Fire-boxes, in number and position to suit the length of the furnace and the character of the ore, are provided. This furnace, in which stirring is done mechanically, is generally provided with an automatic ore feeder.

The Bruckner roaster, which consists of a revolving cylinder with intermittent discharge, is shown in Fig. 170. It is generally lined with fire-brick, the cylinder resting on friction rollers and revolving between a fire-box and a flue. The flame from the fire-box passes directly through the cylinder, and thence mixed with the gases from the ore, into a dust chamber. The cylinder is provided with man-

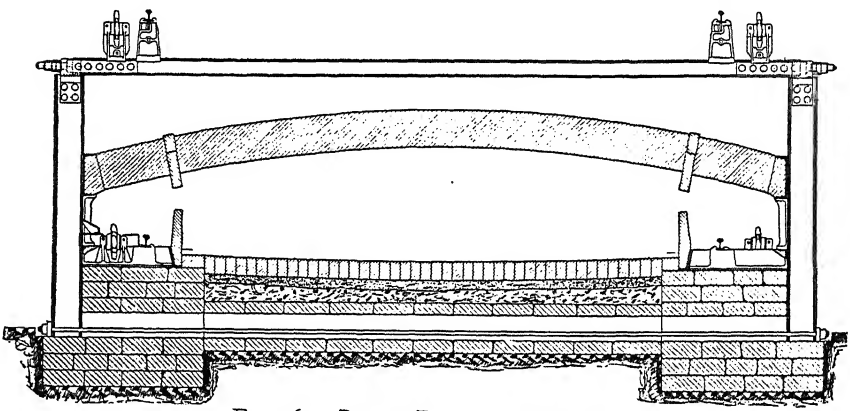


FIG. 169. BROWN ROASTING FURNACE.

holes for receiving and discharging the ore, the latter being roasted in charges of several tons. The advantages of this type of roaster are that the charge of ore may be retained in the furnace as long as required, the heat can be nicely adjusted and the roasting can be completely and economically performed.

A circular multiple hearth shaft furnace is the Stetefeldt roaster. It consists of a vertical brick shaft about 25 feet high, having a fire-box near the bottom and a flue opening near the top; by means of a screw feeder, worked automatically, pulverized ore is continually sifted into the shaft, and, in falling through the heated air, which takes but a few seconds, it is roasted. There is also a fire-box placed at the bottom of the descending flue for roasting the flue dust.

Roasting furnaces having a central shaft, with a number of circular shelves placed at right angles to it and being provided with mechanical stirrers are the Herreshoff roaster and the McDougall

roaster. The latter, which is built by the Allis Chalmer Co., is illustrated in Fig. 171. It is a vertical iron cylinder lined with brick; in it are five or six horizontal hearths constructed of brick. Through the center of the furnace and extending from top to bottom is a

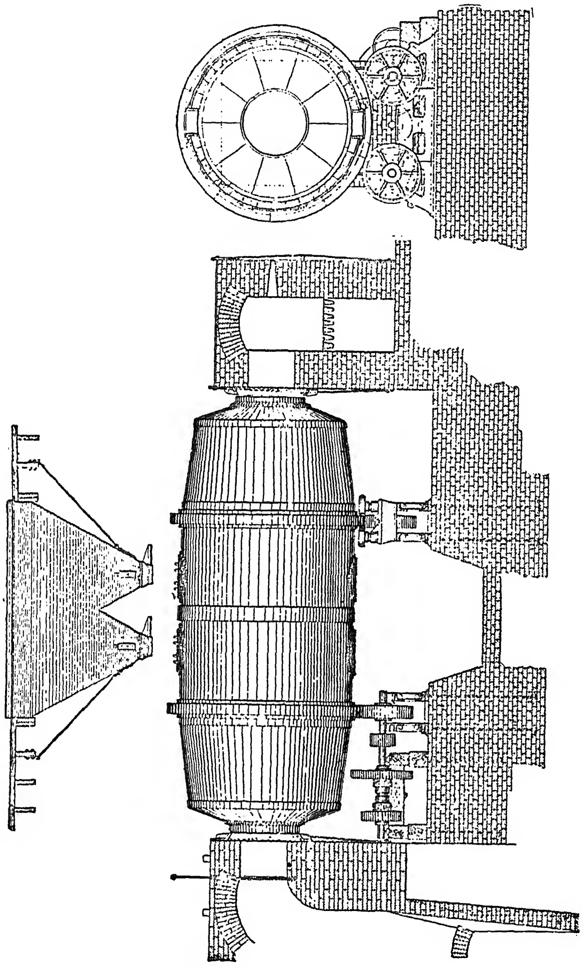


Fig. 170. Bruckner Roaster.

hollow water-cooled shaft, to which are directly connected hollow water-cooled horizontal arms, to which are attached removable and adjustable rabbles.

The ore or matte, preferably reduced to three eighths of an inch or finer, is automatically fed into the uppermost hearth and by the action of the rabbles it is carried towards the center, where it drops through an annular opening onto the next hearth.

On the second hearth the rabbles feed the material gradually outward until it drops through marginal openings in the hearth onto the third hearth.

The rabbles on the third hearth move the material to the center

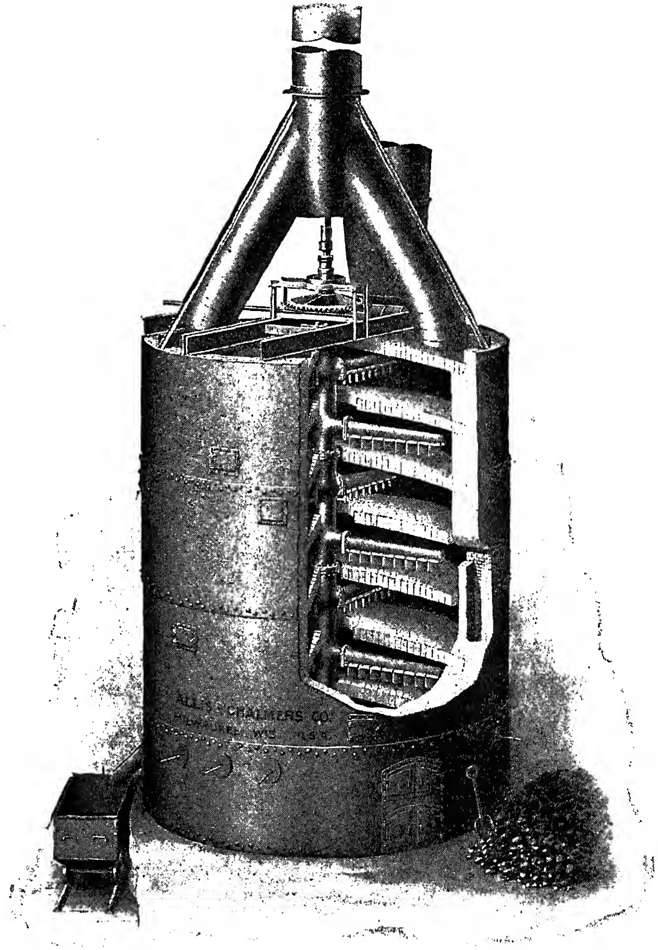


FIG. 171. MCDOUGALL ROASTER.

where it is discharged onto the next hearth and so on throughout the furnace until it is delivered into a receiving hopper.

The hollow central shaft and hollow arms of this type of furnace are provided with a water cooling system, arranged for the circulation of water through the whole interior of same.

This furnace is suitable for roasting ores, concentrates of matte, which contain sufficient sulphur to roast of themselves, not requiring external heat. Ores carrying from 25 to 35 per cent. sulphur can be roasted down to from 5 to 7 per cent. of sulphur by their own heat alone.

For starting the roaster and for keeping it hot when it is shut down temporarily, a circular fire-box is furnished, which is used in connection with two roasters. The usual construction is to put in a fire-box for each two furnaces, simply for keeping up the heat should a shut-down be necessary. For roasting non-combustible matter, the fire-box is incorporated in the furnace, being placed under the lower hearth.

The McDougall roaster is suitable for roasting sulphide ores, the fumes from which are to be converted into sulphuric acid. It is also in demand for roasting ores and mattes for subsequent smelting. The furnace is simple in construction, etc.

The furnace occupies but little space; the smaller size is 15¾ ft. diameter on the outside and 30 ft. high, measured from the ground to the top of the furnace shell.

When running nominally from 1½ to 2 horse power is required, depending upon the speed and capacity desired. If only one or two furnaces are to be installed, it would be necessary to provide more power than stated above, for at times it becomes necessary to put in a plow that will plow up the material on the upper hearth preparatory to putting on new rabbles.

The speed with which the arms and rabbles revolve is determined by the degree of roasting required in the furnace and the character of the ore. At Anaconda the shaft revolves once in 1¼ minutes.

In the Herreshoff roaster two arms are attached to the shaft over each shelf, placed in opposite directions, having teeth or rakes so disposed on the first shelf that the roasting material is plowed from the shaft outward and delivered through openings at the outer edge of the shelf. As the ore drops on the shelf below, the plows are so placed that the material is turned over and over, finally discharging through a large opening around the shaft. The area of this opening is sufficient for the gas that passes through it. The same is true of the openings at the outer edge of the shelf above. The material, after being plowed very slowly over five shelves, finally discharges through two outlets at the outer edge of the bottom shelf. The

furnace has a very large vertical shaft fourteen inches in diameter, made hollow, so that a large quantity of air is drawn up through it; this amount being increased by the introduction of a sheet-iron stack extended above the top of the furnace. Between the shelves there are cross channels passing directly through the shaft at right angles. These channels are about four inches wide and five inches high, and allow ample space around them for the passage of the ascending air. Into these channels or sockets the arms are inserted. In the top of each channel, at the center of the vertical shaft, is a pocket running across the channel; into this a rib at the inner and top edge of the arm locks when the arm is forced into its proper position. The weight of the arm always keeps it properly locked in the channel. By raising the outer end of the arm about three inches the top edge of the rib is brought below the pocket, and the arm can be easily pulled out. Practice has shown that these arms, weighing 100 pounds, can be unlocked and removed from the furnace and new ones put in and locked into place in about one minute.

Each furnace requires from one tenth to one quarter horse power. The labor required is very small. At Butte thirty-six of these furnaces have been running for several years. For the control of their work one man only at each shift is required.

The principal repair is due to the corroding or burning out of the arms. About six arms per year have to be renewed, the cost for these renewals amounting to from twenty to thirty dollars per year.

The ore is fed automatically, by means of a plunger that is moved back and forth in a horizontal cylinder. When going toward the central shaft, the ore is pushed forward and discharged down the curved pipe on the top shelf. When the plunger is pushed back, away from the central shaft, the fine ore descends and fills the vacant space. The mechanical device for the performance of this backward and forward movement is very simple. The central shaft revolves one revolution in two minutes, the plunger making two strokes in the same time. The usual amount of 44 per cent. ore roasted in such a furnace is 7,000 pounds. The roasted ore contains from 2.5 to 3.5 per cent. sulphur.

The central shaft, presenting a large cooling surface, modifies somewhat the temperature of the whole furnace. This is a decided benefit. That portion of the arm where greatest strength is required is maintained below a red heat, as well as the shaft itself. The arms

are hollow and of rectangular cross-section, and made of a composition, which stands the high heat satisfactorily.

Sulphur Furnace. In burning sulphur it is of importance to admit the right quantity of air to sulphur and to utilize the heat of the gas formed for preheating the sulphur. These objects are carried out in an excellent manner in the furnace shown in Fig. 172, which is built by Schutte and Koerting Co., Philadelphia, Pa. The furnace is constructed with a view of easily cleaning the sulphur pan. The sulphur is fed to the pans by means of hoppers which hold a

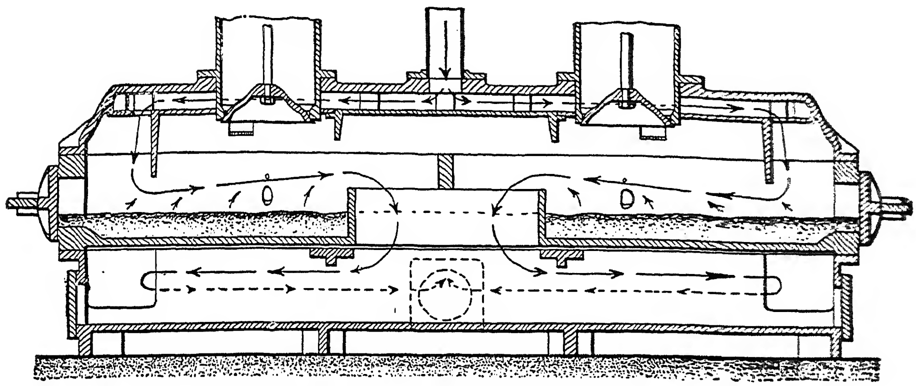


FIG. 172. SULPHUR FURNACE.

sufficient quantity of sulphur to run the furnace for a number of hours without filling up. The hoppers are so arranged that they are closed off from the furnace when filling, therefore the process is not interrupted. Show glasses are provided to watch the proper combustion of the sulphur. Holes are provided on the sides of the sulphur burner to light the sulphur by a red hot iron rod. The advantages of these furnaces are: simple manipulation, no escape of sulphurous acid fumes, continuous working, no brick work. The burning sulphur is visible from outside. Easy cleaning. Greatest efficiency, of at least 95 per cent. of burned sulphur. Arranged for suction as well as for compressed air.

Smelting. Smelting is that metallurgical process in which ores are melted or fused for the purpose of separating their valuable metal constituents from the gangue or worthless portions. It consists essentially in subjecting the ores, mixed with suitable fluxes, constituting a "charge," to the action of intense heat, whereby the "charge" is rendered fluid, the gangue combining with the fluxes

to form a slag or scoria, while the valued metals combine to form an alloy or matte. The separation of the matte and the slag takes place while the materials are in a molten condition, by reason of the difference in their specific gravities.

Smelting is performed either in a blast furnace where the fuel (coke or charcoal) is mixed with the charge, or in a reverberatory furnace in which the fuel (coal, wood, gas or oil) is burned in a fire-box adjoining the smelting chamber.

Smelting may be roughly divided into two classes—"Copper Smelting" and "Lead Smelting." As the terms imply, these mean that the predominating valuable metal in the charge is copper in the one and lead in the other. In lead smelting the valuable product is "lead bullion." In copper smelting, it is "copper matte," when sulphide ores are being treated, and "black copper" when oxide, or carbonate ores are being smelted. The lead bullion, copper matte or black copper contains also whatever gold or silver was in the ores constituting the charge.

For smelting, the charge or mixture of ores and fluxes must be of such a composition that the resulting slag will be sufficiently liquid to allow the valued metal or its compounds to separate from the mass readily and to flow freely from the furnace. The slags produced in smelting consist mainly of silica, ferrous oxide and lime, with which there are frequently small quantities of zinc oxide, alumina and other materials. The amount of these materials in a slag are more of a commercial proposition than a metallurgical one, as the composition of a slag may be varied widely without seriously affecting the running of the furnace, or the extraction of the valued metals.

Custom smelters buy ores of many kinds, mixing them together in proper proportions to form furnace charges of the required composition, thereby making one ore the flux for another. Independent smelters, whose own mines do not produce ores of the composition required for fluxing purposes, endeavor to secure such ores from other sources, as otherwise they would have to add barren fluxes to the charge. These cost as much to smelt as ore and give no results beyond their fluxing powers. Conditions are, however, rarely so favorable that no barren fluxes need to be added. Limestone, iron ore, and, in some cases, silicious material, are nearly always neces-

sary to make a charge. For this reason it is desirable to locate smelters in localities where these fluxes may be easily secured.

The fuel used in blast furnaces is coke or charcoal, or a mixture of the two. Coke is preferable, as it does not crush as readily as charcoal under the weight of the charge in the furnace shaft. The quantity of fuel required by a blast furnace depends upon the character of the ore to be treated, the nature of the fuel itself and the process of smelting involved. In modern lead smelting, the quantity of coke required is, on the average, about 12 per cent. of the weight of the charge. In copper smelting with cold blast, from 8 per cent. to 12 per cent. coke is required, while with hot blast and ores running high in sulphur, as little as 2 per cent. of coke has given good results.

For reverberatory furnaces, coal, wood, oil or gas may be used as fuel. The quantity required depends upon the character of the ore, the nature of the fuel itself and the design and size of the furnace. In large, modern reverberatory furnaces using ordinary run-of-mine bituminous coal, 500 to 1,000 pounds of fuel are used per ton of ore smelted.

An important advantage of smelting is that nearly all ores, when properly fluxed, can be treated by this process. The extraction of the valued metals in smelting depends principally upon the character of the ores, but is also largely dependent upon the man in charge of the plant. Ordinarily it is safe to figure that practically all of the gold, 95 per cent. of the silver and 90 per cent. or more of the lead or copper will be saved. The cost of smelting depends upon the character of the ore, the cost of coke and labor, the size of the plant and its equipment and arrangement. In some large plants, equipped with the most modern machinery and operating under very favorable conditions, a cost as low as $1.25 per ton has been attained, while with small plants in remote localities, where fuel and labor are expensive, the cost will run up to $15 per ton or higher.

Success in smelting is primarily dependent upon having a plant equipped with the best and most modern machinery. The arrangement of the plant should be such that ample working room is provided around the furnaces. Rehandling of materials should be avoided as far as possible and hand labor eliminated wherever it is practicable to put in mechanical means for performing the work. A smelting plant should be carefully designed, and every condition that

will influence the cost of operation should be carefully considered when the equipment is being decided upon and the plans made. It is often the case that a few additional dollars spent in equipment will mean the saving of thousands in operating expense. Even in a small plant a saving of a few cents per ton of ore handled amounts to a considerable sum at the end of a year's run.

A modern blast furnace for lead smelting consists essentially of a brick shaft resting upon a suitable mantle frame carried by four columns at the corners of the furnace. Below this shaft is a set of water jackets of steel or cast iron, which form the smelting zone, suitable openings being provided near the bottom of the side jackets for the tuyeres, through which the blast is introduced. Below the jackets is a fire-brick crucible encased in steel or cast-iron plates, and known as the "curb." The brick shaft may terminate at the charging floor, the downtake or flue for conducting away the gases connecting with the shaft just below the charging floor. The top of the shaft is covered and provided with openings for charging the furnace, or the shaft may extend above the feed floor, terminating in a stack extending through the roof of the building, suitable openings being provided in the sides of the shaft at the feed floor for charging. In the latter type of furnace the downtake connects with the shaft at some convenient point above the feed floor. The downtake in either case connects at its opposite end with the dust chamber or flue, which leads the gases to the main stack of the plant. In the crucible of the furnace, the molten materials separate, the lead settling to the bottom of the crucible and being removed through an inverted syphon passage provided in the brick work of the curb. The slag passes out through a tap-hole at either one side or end of the furnace.

A silver-lead furnace, as built by the Wellman-Seaver-Morgan Company, Cleveland, O., is shown in Fig. 173.

Blast furnaces for smelting copper ores are similar in general form to those used for lead smelting, but in detail they differ from them materially. The internal crucible is either quite shallow or is dispensed with entirely, as in the case of matting furnaces where the molten materials pass at once from the furnace into an external crucible known as the "settler" where the separation of the matte and slag takes place. The jackets are much higher than in lead furnaces, extending in many furnaces up to the charging floor. In

this case they are made in two tiers or sections. The tuyere boxes are of the rigid type and connected with the bustle pipe by light steel tubing. The mantle frame and supporting columns and the

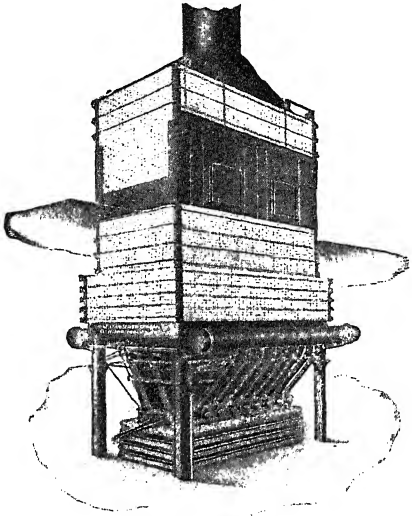
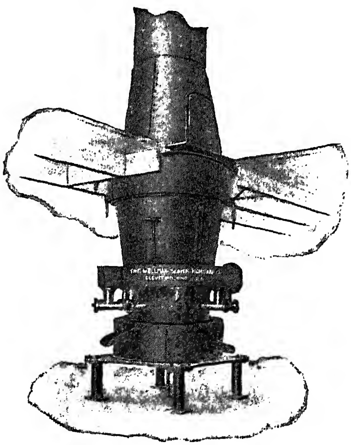


FIG. 173. SILVER-LEAD FURNACE.

structure above the mantle frame are much the same as for lead furnaces. Large copper furnaces are built rectangular in shape; small furnaces round.

Fig. 174 shows a round, Fig. 175 a rectangular copper furnace built by the Wellman-Seaver-Morgan Company, of Cleveland, O.



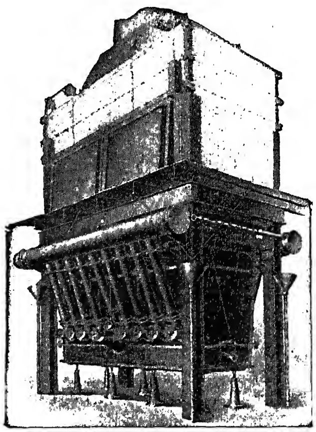


FIG. 174. ROUND COPPER FURNACE.
FIG. 175. RECTANGULAR COPPER FURNACE.

Copper converters are of different shapes and sizes, though in general appearance they are more or less similar to the vessel used for bessemerizing iron.

Converter shells are made of heavy steel plates riveted together. They are supported either on trunnions or rollers, and are tilted by hydraulic or electric machinery. For convenience in re-lining, the top is separable from the body.

The capacity of converters may vary from three to ten tons, the capacity of a newly lined converter being less than it is after several "blows," as the lining is being continually eaten away.

An electrically operated copper converter, as manufactured by the Wellman-Seaver-Morgan Co., of Cleveland, O., is shown in Fig. 176.

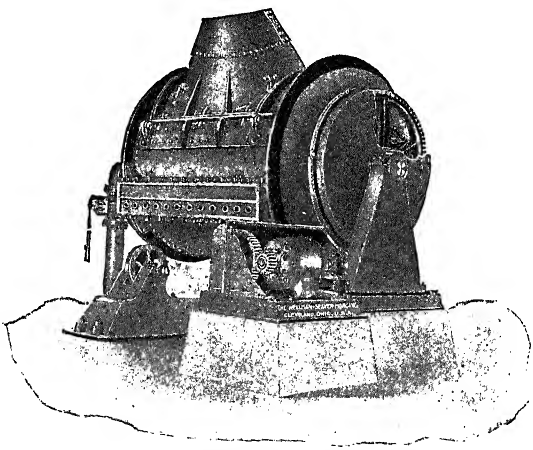


FIG. 176. COPPER CONVERTER.

A hot blast is quite advantageous in the smelting of some sulphide ores. As a general rule, however, it has metallurgically no particular advantage over a cold blast, and its use is, therefore, generally a purely commercial proposition; that is: Will the value of the coke saved by its use, after deducting the cost of fuel, labor, repairs, interest and depreciation in the heating apparatus, yield a sufficient margin to warrant its installation?

Where coke is expensive, and coal, wood, oil or other suitable fuel that can be used to heat the blast are cheap, the hot blast will undoubtedly pay well for installation, but where the cost of these fuels is relatively the same as coke, the saving by its use does not warrant the installation and up-keep of the hot blast apparatus.

The foregoing, of course, assumes that hot blast will have metallurgically no advantages over cold blast.

In the smelting of some ores, however, a hot blast is desirable and in some instances absolutely necessary, but as a general rule the foregoing holds true.

In copper smelting there is no combustible gas discharged from the furnaces, as is the case with iron smelting, and the many devices that have been designed to heat the blast by means of the slag, flue gases, and in like ways have met with small measures of success.

The most satisfactory means known of producing a hot blast is the simple "U"-pipe cast-iron stove, heated by coal, wood, oil or other fuel burned in its fire-box. In these stoves the cold blast from the blower enters the stove from the main header over the back of the stove, and passing through the various "U"-shaped pipes and bases, is heated by the fuel burned in the fire-box and discharged hot into the header over the front of the stove, and from there conducted to the furnace.

A hot blast stove, as built by the Allis Chalmers Company, Milwaukee, Wis., is shown in Fig. 177.

Refuse Destructor. An extremely interesting type of a reverberatory furnace is the "Heenan" refuse destructor, by which the problem of economical destruction of city refuse seems to be solved. Fig. 178 illustrates this furnace. The combustion air is preheated before entering the furnace chamber by passing through the air heater which is kept hot by the products of combustion. The sensible heat of the discharged clinkers is also utilized for heating of the blast, which is conveniently done by the arrangement of the ash pits in separate compartments. The illustration shows how the material is charged to the furnace, the air valves for regulating the volume of the combustion air, and the utilization of the sensible heat of the products of combustion for heating steam boilers, besides the air heater mentioned above. The temperature obtained in this furnace is always above 1300° F., which is an excellent result if the low thermal efficiency of the material charged into the furnace, which is a mixture of household ashes and rubbish, is considered.

Calcination. The glowing of products is generally carried out in similar furnaces as the melting and is called calcination in the chemical industries.

Calcination is used for removing certain substances, for instance

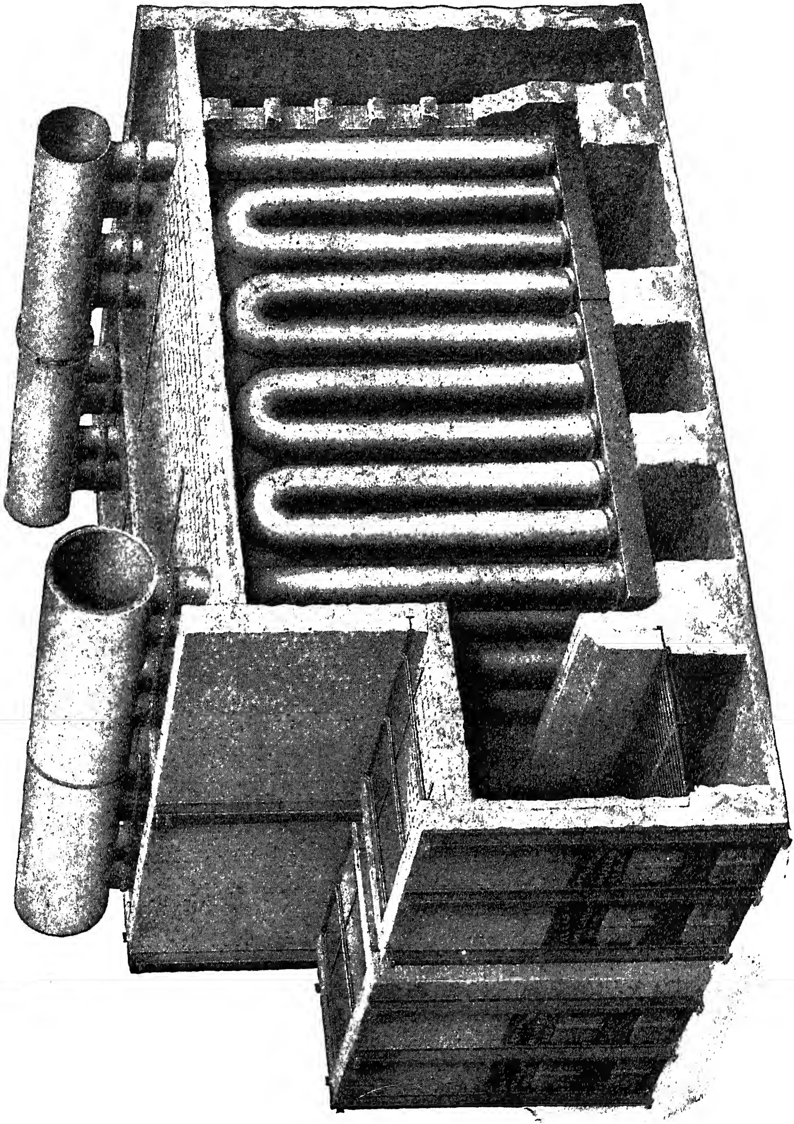


FIG. 177. HOT BLAST STOVE.

water, from a material by means of heating. The furnace shown in Fig. 168 and also shaft furnaces are used for this purpose. Sometimes cast-iron retorts are used for calcining.

A very durable and economical construction of a calcining and

evaporating furnace is shown in Fig. 179 (designed by Friedrich Siemens in Dresden). In this furnace the radiant heat of the active flame comes into effect only in the calcining space below the evaporating kettle. The neutral products of combustion are also taken off from this space *C*, so that the evaporating pan *A* is heated only by local circulation of the firing, which is effected by connecting channels *c*1, *c*2, *c*3 provided between the calcining hearth and the pan in the space *H*.

The heat of the products of combustion leaving the calcining space

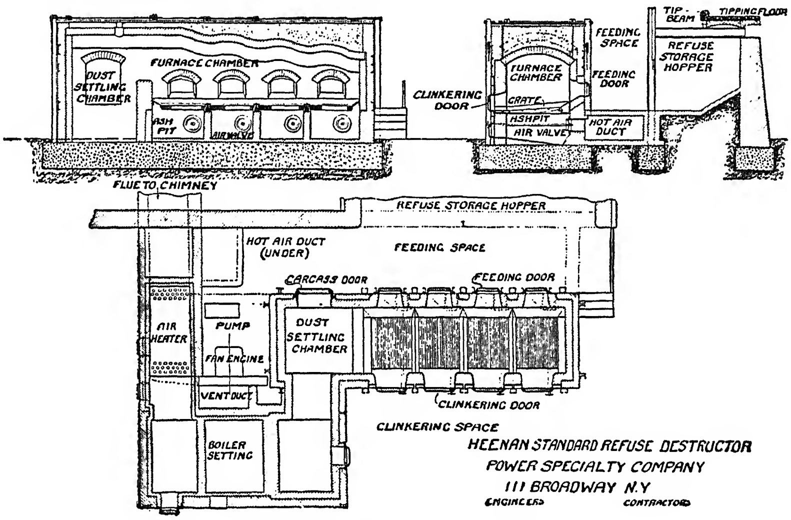


FIG. 178. REFUSE DESTRUCTOR.

is utilized for preheating the combustion air, whereby the temperature of the heating flame and its capacity for heat radiation is increased.

The heating of an evaporating pan, effected by local circulation of the fire-gases, insures the greatest uniformity in heating, long life of the pan, no warping of the material (cast iron), great capacity and low fuel consumption. It also prevents the formation of crusts.

Solid, liquid or gaseous fuel can be used in this furnace; in the furnace shown in the illustration gas firing is used, which is very suitable in most cases.

The gaseous fuel goes through flue *g* to the furnace, is mixed with the air (coming from flue 1) in chamber *R*, travels as flame through flue *f* into the calcining space, and is finally escaping through the chimney. The exchange of heat between the calcining space *C*

and the evaporating pan *A* is effected by the channels *c*1, *c*2, *c*3 already mentioned. For increasing the heat of the pan, if required, there are also provided openings in arch *G*, which can be closed or opened (for decreasing and increasing, respectively, the heat).

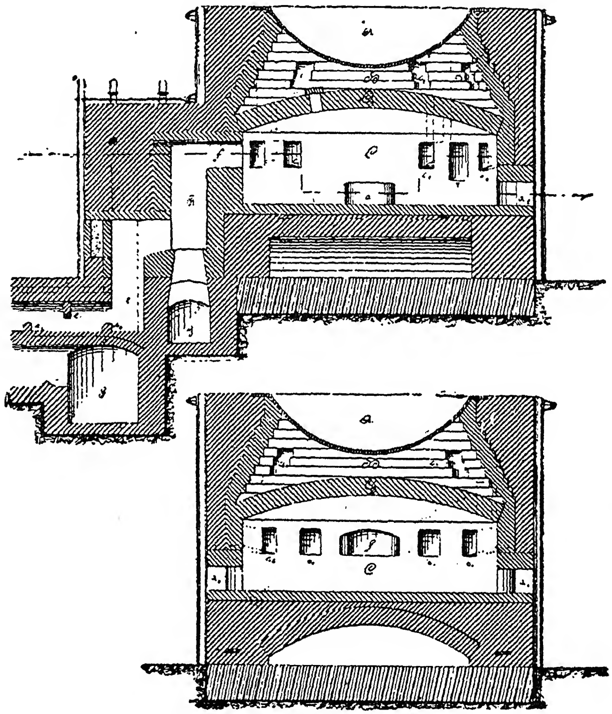


FIG. 179. CALCINING FURNACE.

The openings of the channels *c*1, *c*2, *c*3 can also be regulated by means of fire-bricks. The material to be calcined is transported from the pan to the calcining space by means of inclined planes in the brickwork; it is distributed and worked through the working doors *a*1, *a*2.

Water Gas. Water gas is used in this country only to a small extent, as the processes now employed for its production are uneconomical and expensive to install. In these plants water gas is made by blowing steam through incandescent fuel and heating the latter up at certain intervals by blowing air through. Generally gas is made for about four to five minutes, and air blown for the four to five minutes following, etc. During the hot blowing period

a poor producer gas is formed, which can be utilized only under favorable local conditions. The long intervals between the gas making periods necessitate the use of a very large holder, and in places where the producer gas has to be used, a second holder has to be installed, which means a large increase in the first cost.

In Europe great strides have been made in this art; the first cost of apparatus has been considerably reduced, and the yield in water gas doubled. European engineers have entirely done away with the production of producer gas in this process. By using a lower layer of fuel, and an air blast of certain pressure, the making of water gas is carried on now continuously for eight to nine minutes, and then hot blowing is done for three quarters to one minute. The handling of the apparatus is simplified and made absolutely safe by an interlocking valve device. The size of the holder is decreased, the first cost reduced, and the introduction of this valuable gas greatly facilitated. These plants are used for melting, heating, evaporating, etc., and wherever a high temperature is required or an exact temperature to be maintained; also if a reaction is to be performed with a reducing flame; further for: open hearth and crucible steel melting; annealing, brazing, tempering, soldering, forging, etc.

Thirty-five to forty c.f. of gas of 285 B.T.U. heating value are obtained by this process from one pound of coke.

The generator, which is a cylindrical shell, lined with fire-brick, and provided with the necessary valves for entrance of air, etc., is filled with coke to a certain height and blown hot by means of a positive blower. During this period the air inlet valve and the charging door on top leading to the flue are open and the gas valves closed. The air enters under the grate and goes through the fuel to the stack. When the generator is sufficiently hot, the air inlet and charging door are closed, and at the same time the upper or lower gas valves are opened, depending upon where the gas is to leave the generator. Then steam is blown into the fuel until the gas becomes poor in quality, which can be seen from a test flame. Chemically the process consists of the combination of the oxygen of the steam with the carbon of the coal to form carbon monoxide, and hydrogen is liberated as represented by the formula

$$H_2O + C = CO + H_2.$$

The average composition of the water gas is: H 50 per cent., CO 40 per cent., CO 3.5 per cent., N 4.3 per cent., CH_4 0.7 per cent., O 0.5 per cent.

When the quality of the gas deteriorates the steam valve is closed,

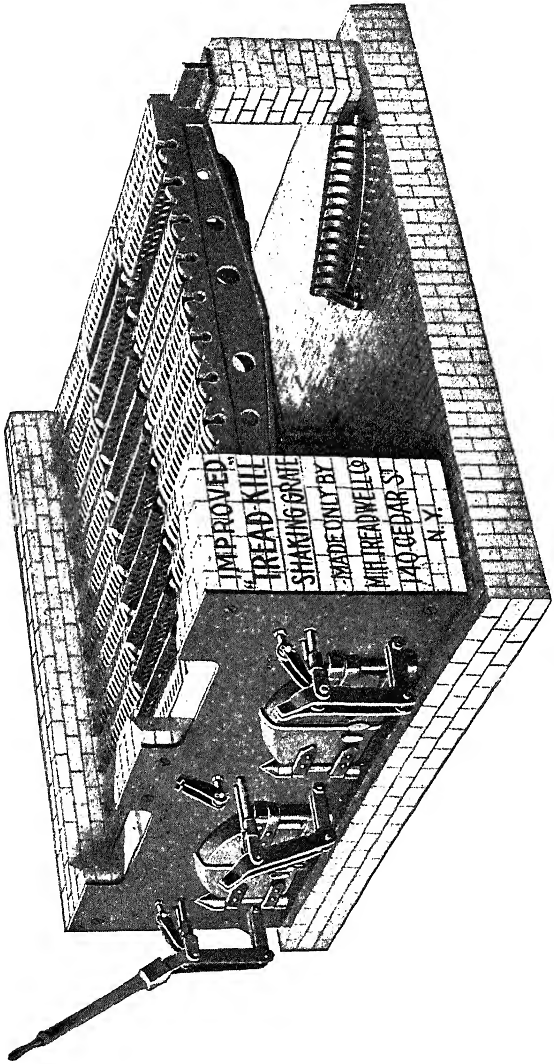


FIG. 180. SHAKING GRATE.

the air valve and charging door opened, the gas outlet closed and the blower started. In this way air and steam are blown alternately through the generator. The steam is blown in from the top and

from the bottom alternately to make the distribution of the heat in the generator more uniform. Fuel is charged through the charging door after three periods of gas making. The generator is provided with tight doors, through which clinkers and ashes are removed.

The air and gas valve are interlocked, so that they cannot be opened at the same time; when the air valve is opened the gas valve is locked and vice versa. This insures absolute safety. The generator and all the valves are worked from a platform. The water gas after leaving the generator goes to the scrubber, which is filled with coke and sprinkled with water; from here the gas goes to a small holder, which serves as an equalizer.

Direct Coal Firing. For facilitating the removal of ashes and clinkers and for reducing at the same time the cost of attendance,

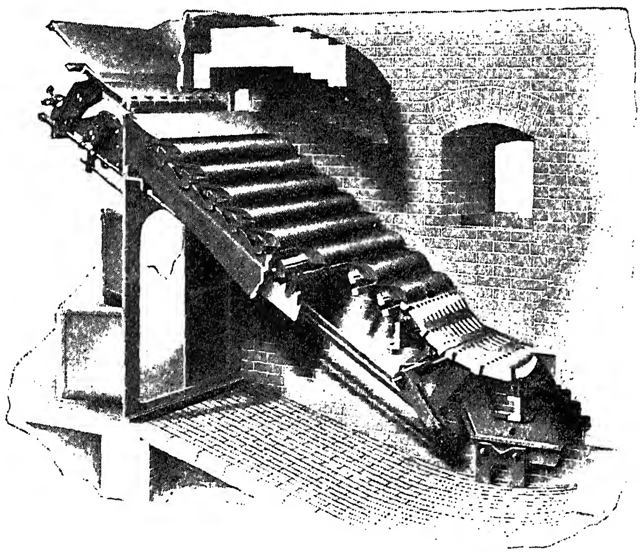


FIG. 181. RONEY STOKER.

shaking grates are widely used in place of stationary grates. Fig. 180 illustrates the construction of a shaking grate.

In large plants automatic stokers are used to great advantage, as they not only effect a great saving in labor, but also allow the smokeless combustion of soft coal. The most popular and one of the best stokers on the market is the Roney stoker, Fig. 181, which is built by the Westinghouse Machine Company. The coal is fed into a hopper extending across the boiler front, usually by gravity

from an overhead bin. From this hopper the fuel is automatically supplied to the furnace by a reciprocating pusher operated by the rock shaft by an eccentric. The fuel descends through the throat of the arch on to the upper grate bars, where it is subjected to an intense heat radiated from the incandescent fire-brick arch spanning the upper portion of the furnace. This entirely cokes the fuel and drives off all the volatile gases, leaving the coke, which is then gradually worked down the inclined surface by the rocking motion of the grate bars, imparted to them from the eccentric on the rock shaft.

The oscillation of the grate bars not only works the fuel slowly down the furnace, but also keeps it constantly agitated, thus preventing to a large extent the formation of clinker, and bringing the fuel into intimate contact with the incoming air. After the solid combustibles have been totally consumed the remaining ash is discharged on to the dumping grate at the bottom of the furnace. The operations necessary to clean the fires are very simple. First the guard is raised to a position which prevents the fuel bed from sliding. Next the dumping grate is dropped, permitting the ashes to fall over the ash pit.

In the Roney stoker all the essential conditions necessary to high rates of combustion and smokeless operation have been realized. Fuel is fed to the furnace at a uniform rate and is coked in the presence of a preheated air supply; the combustible is brought into intimate contact with the required quantity of air for complete combustion.

For heating long kilns, such as are used in the cement and other industries, coal dust firing is extensively used. At present the Schwarzkopff firing, in which the coal dust contained in a hopper is conveyed to the fireplace by means of a rotating brush, is very popular. A new system of coal dust firing, the "Aero," is described in the chapter on "Grinding."

Oil Firing. Steam jet oil burners are adapted for small plants and where the fuel is heavy and viscous. The fuel is atomized by means of a jet of steam, a mixture of air jet and steam, or air jet. The bare steam jet should be employed for spraying heavy fuel like tar. For light fuels a mixed jet (steam and air) or air only can be used. Fig. 182 shows a steam jet oil burner for tar. The latter is lifted to the tank on top of the burner by means of a steam

jet exhauster and flows from the tank to the burner by gravity. *S* is the steam pipe, *E* the steam jet exhauster, *SC* is the steam coil for heating. The tar should be heated in the tank, if possible, to about 150 degrees Fahrenheit. With fuel oil the regulation is accomplished by means of cocks, and no special heaters or strainers are required.

With these burners the fire is started as follows: A scoop or tray containing oil is mounted on the fire-brick and the oil is ignited, the temperature of the boiler rising slowly but continuously. If there is steam in the boiler the plant is started as follows:

1. Full draft is put on, so that all gases which might have remained in the fire room will draw off. This is done to prevent explosion. Steam is now carried to the heaters and the pump started, which circulates the oil through the pipe until the proper temperature of the oil is reached; then the oil is ignited.

2. If there is no steam pressure on the boiler, then the warming up arrangement should be started. When starting the oil-firing plant, smoke will appear until the walls of the fire room are heated to such a temperature that the flame is not cooled off. When stopping the plant, the air admission has to be closed, so as to prevent an excessive cooling of the boilers.

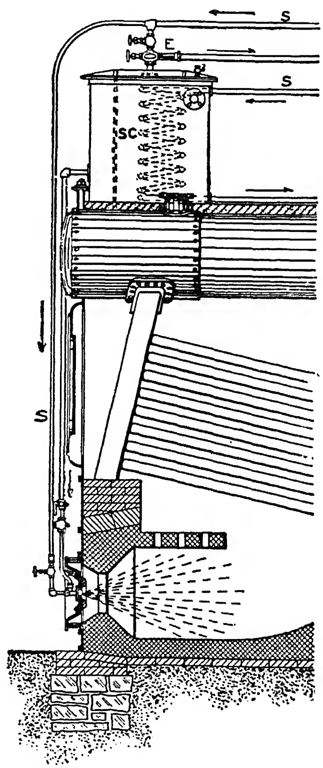


Fig. 182. Steam Jet Oil Burner for Tar.

A more elaborate type of an oil burner which insures strict economy and reliable services is the Koerting patent oil-firing system with centrifugal spray nozzles which, as also the oil burner mentioned above, is built by the Schutte and Koerting Co., Philadelphia, Pa. In this system the oil flows from the supply tank to a central pumping outfit, where it passes through a primary heater and flows through filters to a pressure pump. The pump passes it under a

pressure of thirty to seventy-five pounds, according to the evaporation required, and presses it through a second heater to the centrifugal spray nozzles directly in front of the boilers. In this second heater it is heated to 220° to 260° F., which means the oil is heated above the boiling or flash point at atmospheric pressure. Evaporation of the oil is prevented by the pressure on the pumps being kept in accordance with the temperature. However, the moment the oil leaves the spray nozzles under the boiler, the pressure is removed from the oil and thence it flashes into the finest atoms. This physical action is assisted by the mechanical atomizing of the centri-

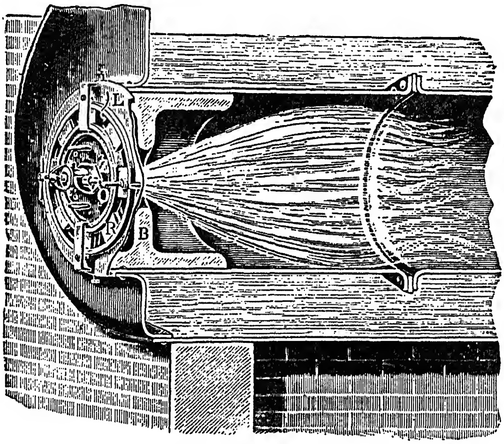


FIG. 183. KOERTING PATENT OIL FIRING SYSTEM.

fugal spray nozzles, the result being a perfect and intimate mixture of the air with the oil. This gives the desired result of a smokeless and perfect combustion. The installation of such a burner is shown in Fig. 183.

The application of the centrifugal sprayer obviates the defects of the steam jet system, and secures several important advantages. In spraying crude oil or fuel oil, etc., by means of steam jets, a certain portion of the heating value of the fuel is lost, as the steam has to be raised to the furnace temperature, and, being used for spraying, is lost to the boiler. With the nozzle system there are always two pumps installed; one in reserve; two filters are furnished, to be used alternately, and the pressure pipe from the pump is provided with two strainers. The steam used for pumping, likewise

for heating, is recovered as condensed steam and returned to the boilers. A steam pressure reducing valve maintains a constant pressure and minimizes the attendance. An overflow and safety valve prevents the oil pressure from rising, which obviates a waste of fuel. An air vessel, which maintains a uniform velocity in the pressure pipe line, forms part of the apparatus. Oil and steam pressure gauges, thermometer and oil line complete the outfit.

CHAPTER XI.

SEPARATING.

Filter Presses. There are many people to-day operating large plants who, if they understood the applicability of the filter press to their particular case, could effect considerable saving by the recovery of materials which to-day are going to waste, or by improving their present methods of filtration.

As in large industrial operations it is desirable that the process of filtration be conducted with the greatest possible economy, the selection of the proper kind of filter press is of great importance. Those herein described and illustrated are manufactured by T. Shriver and Company, Harrison, N. J., the largest manufacturers of filter presses in the United States.

In its simplest form a filter press consists essentially of a series of chambers, formed either by recessed plates (Fig. 184) or by

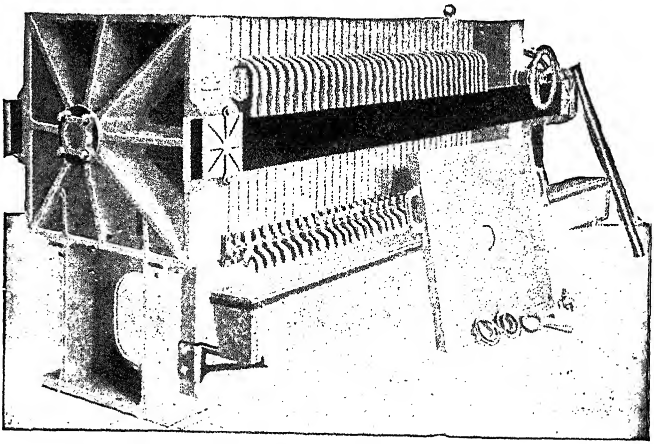


FIG. 184. RECESSED FILTERPRESS.

flush plates with frames between them (Fig. 185). These plates and frames have a lug or handle projecting from each side, the lugs resting on a pair of parallel bars.

One end of each of these bars is secured to the front or head of the press. The plates and frames rest upon them, and the back

or follower is forced up against the plates by means of a heavy screw or hydraulic plunger in a yoke or screw standard, to which the rear end of each bar is secured.

Over the surface of each plate is stretched the filtering medium, either cloth or paper, or, in some cases, both. The material to be filtered is pumped in through a channel in the head of the press and is distributed over the surface of the filtering medium, the liquid passing through and out of the cored channels in the plates, while the solid material is retained on the surface of the filtering medium, gradually filling the chambers until a solid cake is formed in each. The press is then opened and the cakes are removed. It is then closed again and the operation repeated.

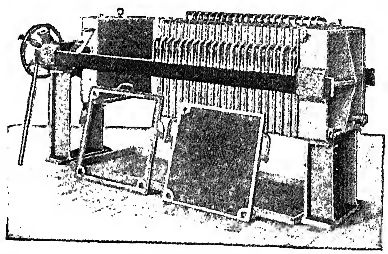


FIG. 185. FLUSH PLATE AND FRAME FILTERPRESS.

In the "recessed filter press" the material to be filtered is pumped in through a channel in the center of the head and passes on through a hole in the center of each plate, thus filling all chambers simultaneously, and the filtrate runs out through cocks or bibs provided near the bottom on the sides of the plates. It runs into a trough, which is connected by piping with a suitable tank or receptacle. The advantage of using cocks is that in case a single cloth breaks, that plate may be shut off and the filtration continued.

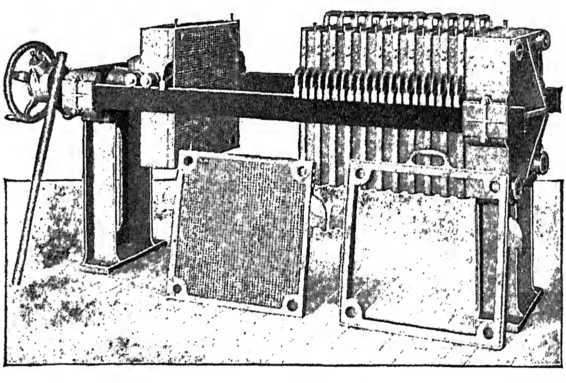


FIG. 185A. FLUSH PLATE AND FRAME FILTERPRESS FOR VARNISH WORKS.

The "flush plate and frame filter presses" have the inlet on one

side of the head instead of in the center, and the material passes along through holes in the handles of the plates and frames. This cored channel is kept from leaking by using rubber collars inserted in the holes of each plate. In this type no holes have to be cut in the cloths.

The thickness of the cake varies from one to six inches; with materials that form a dense cake thin cakes have to be produced, and vice versa.

For freeing the cake in the filter press from adhering liquid particles, most filter presses are provided with a washing arrangement, by means of which the cakes can be washed with water, diluted acids, lyes, benzene, alcohol, etc. For this purpose one extra channel is provided in every filter plate and chamber respectively. The channel has an inlet to the surface of every second plate only, the outlet cocks of which are closed, and the washing liquor passes behind the cloth (*i. e.*, behind the cake) into the press, goes through the first filter cloth, then through the cake and leaves finally through the outlet cock of the other plate, carrying along the liquid displaced

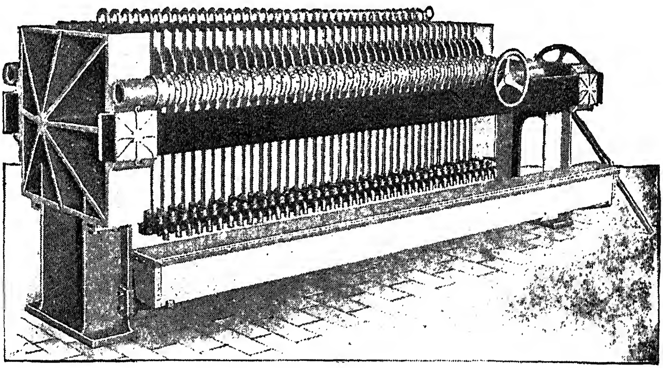


FIG. 186. STANDARD FILTERPRESS.

from the cake. The object of washing the cakes is either to produce as pure a solid as possible, or to recover the liquid, which would otherwise remain in the cake. The cake can be treated, while in the filter press, with any liquids for dissolving soluble components from the cake.

In certain cases the mass to be filtered has to be kept hot or cold during filtration; hence for these purposes, channels or coils are provided in the plates for the circulation of steam, hot water, cold

water, or a refrigerating mixture, respectively. The connection of the channels or coils from chamber to chamber is perfectly tight,

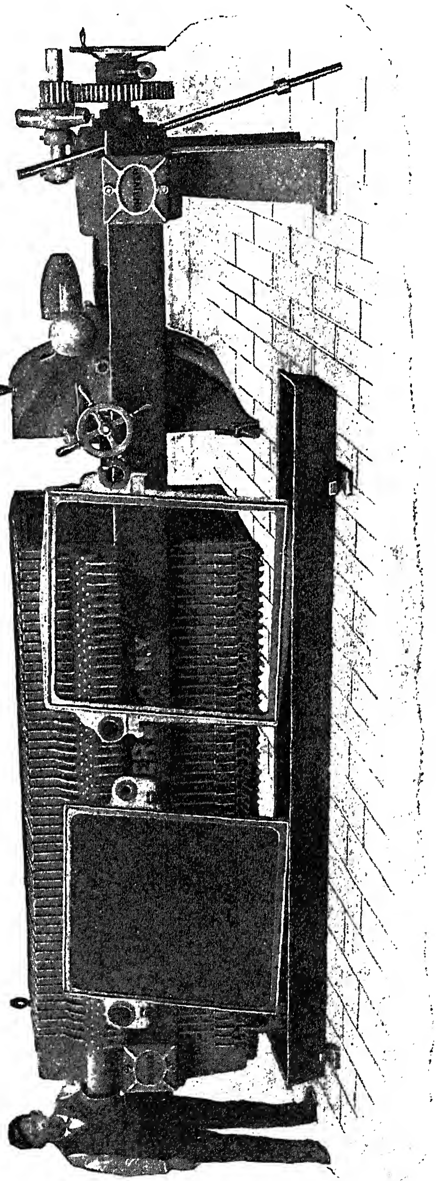


FIG. 187. MONSTER FILTERPRESS.

so that the mass to be filtered cannot come in contact with the heating or cooling substance.

Heated chambers are used for materials that can be filtered only in molten state (wax, ceresine, etc.) or for liquids from which salts would crystallize out at a low temperature. Cooled chambers are used, if substances are to be separated, which solidify at a low temperature only (clarification of cod liver oil, etc.).

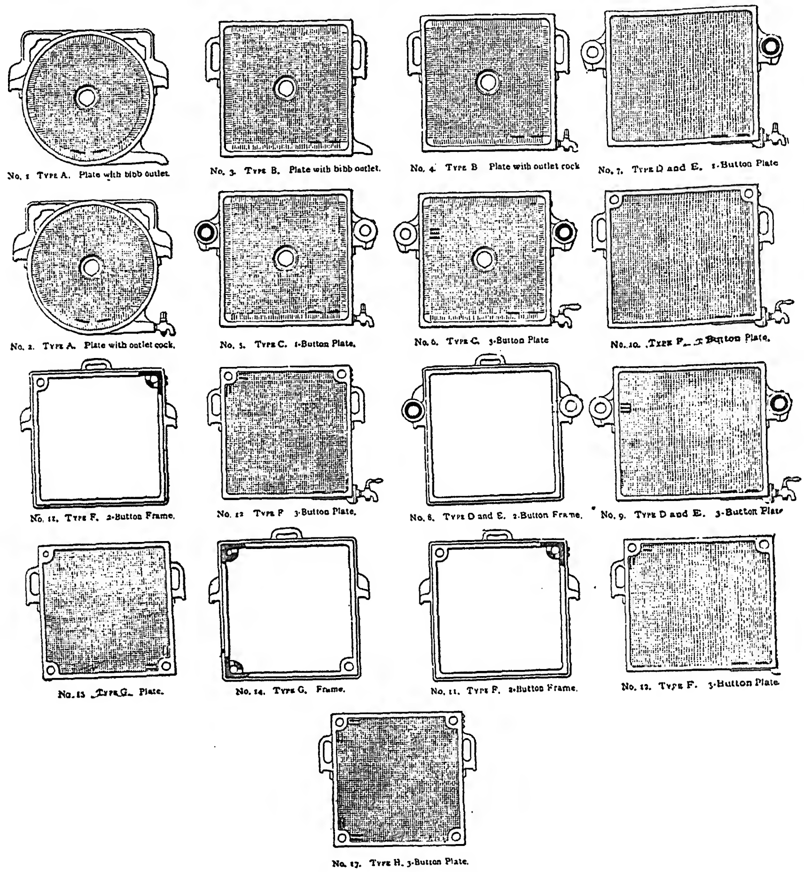


FIG. 188. ARRANGEMENTS OF CHANNELS IN FILTERPRESSES.

A very popular type of filter press is shown in Fig. 186, while in Fig. 187 a monster filter press is illustrated.

In Fig. 188 are shown the most common arrangements of the various channels. The cases shown differ from each other with respect to the following four points:

1. The filtrate discharge outlets may be closed or open or regulated by means of cocks.

2. The chambers may be provided with or without a washing arrangement.

3. The method of introducing the washing liquid may be varied.

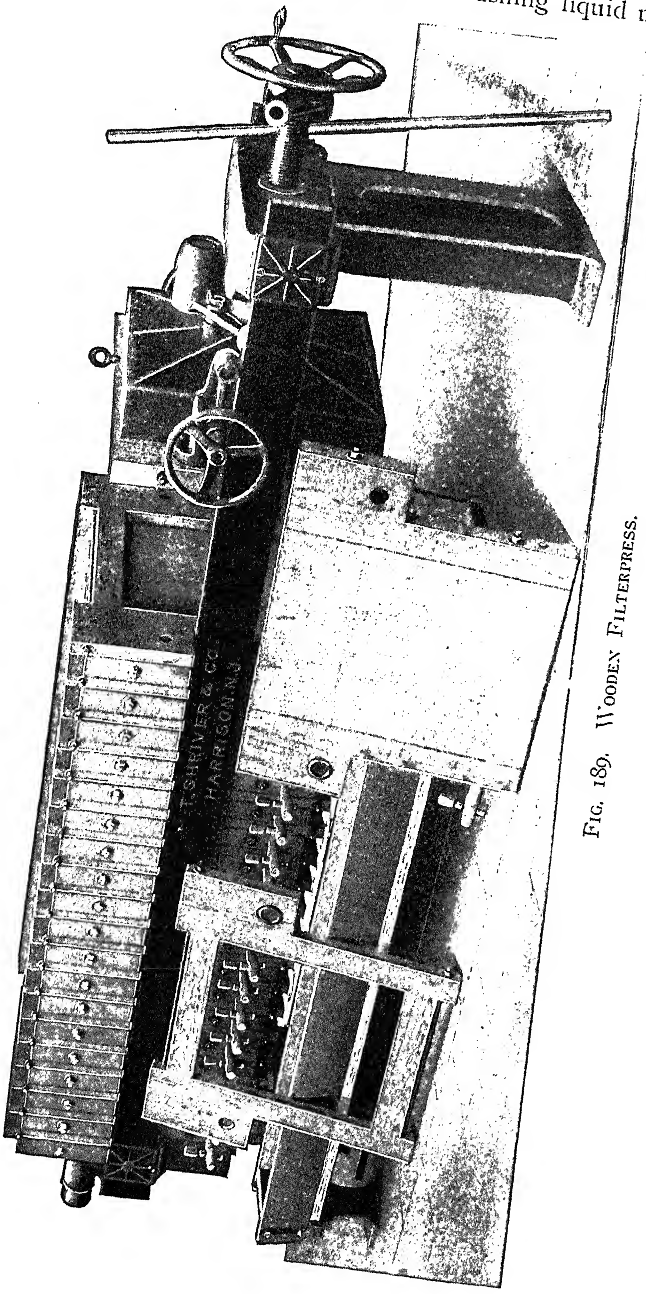


Fig. 189. Wooden Filterpress.

4. Feed channels may be either inside or outside of the plates. With outside channels it is unnecessary to cut a hole in the filter cloth, so that its life is prolonged.

The materials used in the construction of filter presses depend upon the liquids to be filtered. For the liquids which do not attack iron, iron is the best material. For acids, wood (Fig. 189), bronze or hard lead is used; and of late aluminum filter presses have come to the front.

For filtering volatile materials the filter press shown in Fig. 185A can be used, since in this type the filtrate is discharged through a pipe at one corner of the head and therefore can be kept from exposure to the atmosphere.

Fig. 190 illustrates the pyramid surface on filter plates which has decided advantage over the corrugated surface or screens, having 27 per cent. higher efficiency than the corrugated surface and 70 per cent. higher than the screens. In using a screen the filtrate passes through the cloth only where the holes in the screen occur. With the corrugated surface the filtrate passes through the cloth only at the corrugations, but with the pyramid surface the filtrate passes through the whole surface of the cloth, with the exception of the very small surface on the top of the pyramids.

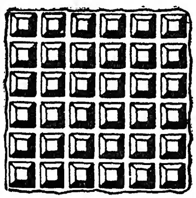


FIG. 190. PYRAMID SURFACE OF FILTERPLATES.

The closing devices mainly used on filter presses are easily understood from the illustrations (Fig. 191).

The outlet cocks also play an important part in the successful operation of a filter press. The flap cocks (Fig. 192) are especially designed for this purpose. They are very simple in construction and cannot get out of order; the cored channel through which the filtrate passes is large in area and there are no obstructions. To close them, a flap faced with rubber or leather, as the case may require, is pressed down with a handle against a faced end on the cock, and without any undue pressure will close the cock, so that it will stand a very high pressure without leaking.

For obtaining perfectly clear solutions, which is quite difficult by the use of filter cloths, a so-called three-chamber press has been constructed, in which filtration is effected by sand, etc., contained in the press, instead of using cloths. Fig. 193 shows the general

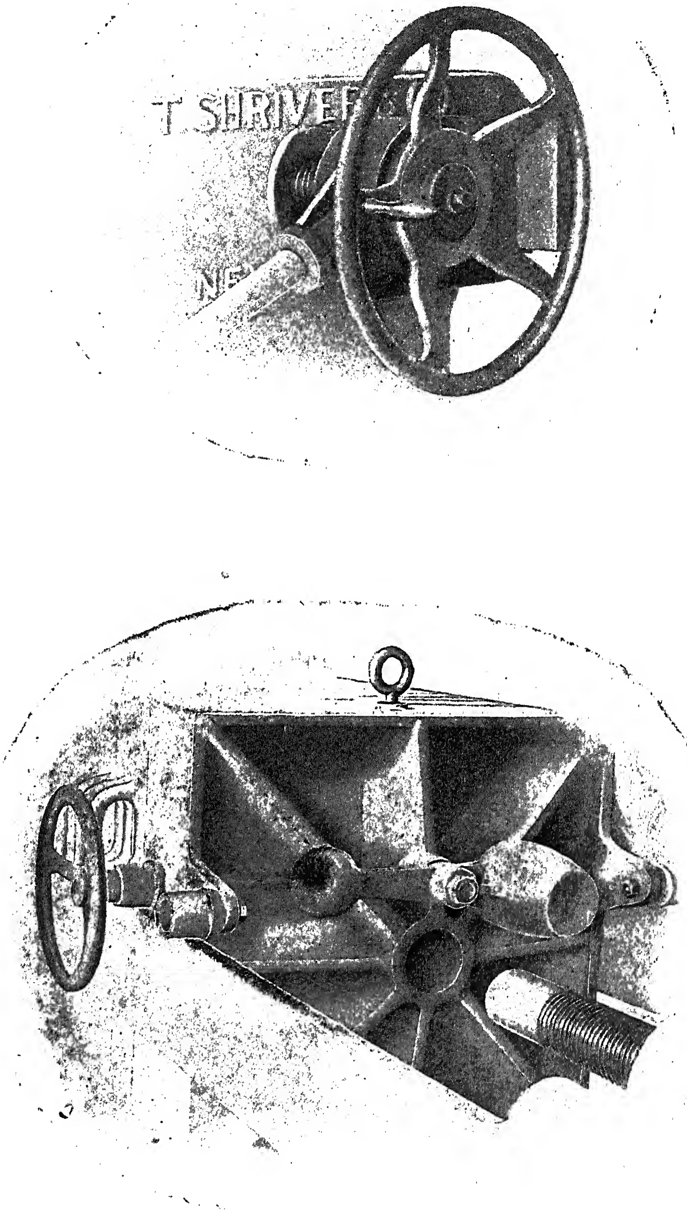


FIG. 191. CLOSING DEVICES FOR FILTERPRESSES.

arrangement; between two frames *a* plate *c* is provided, while at the other sides of the frames *a* the plates *b* are arranged. The plates *b* and *c* serve for discharging the liquid during the preparation of the filter. The filtering material—sand, coal, etc.—enters the frames *a* at the top in a form of a thin paste and is transformed

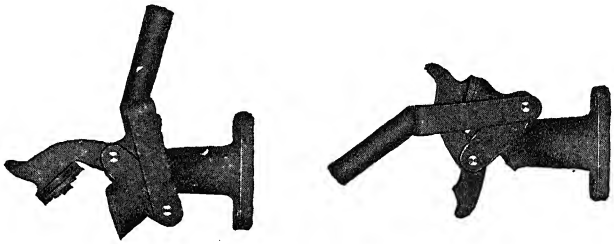


FIG. 192. FLAP COCK.

into a solid cake, while the liquid runs off through the corrugations of the plates *b* and *c*.

After the filter has so been formed in the frames *a*, the plates *c* are replaced by plates *d*, while the plates *b* and the frames *a* remain in their place. Now the material to be filtered enters at the top at *d*, passes from right to left through the frames *a*, which are filled with sand, coal, etc., and the liquid is discharged perfectly clear

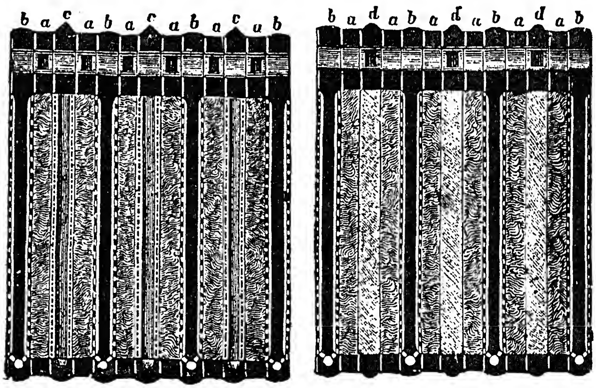


FIG. 193. THREE CHAMBER PRESS.

through the cock of plate *b*. These presses are built of iron and wood, with or without washing arrangement.

A filter press for experimental laboratory purposes is built by most filter press manufacturers.

The washing of the cloths is an operation of some importance,

and should be performed in suitable washing machines, as shown in Fig. 194. Such machines are also furnished by T. Shriver and Company.

Centrifugal Separators. Another appliance for separating liquids from solids is the centrifugal. In this machine the solid material to be separated from the liquid is pressed by the centrifugal force generated by the high speed of rotation towards the walls of the basket, while simultaneously the liquid escapes through the perforations of the basket into the curb. These machines are used in finishing establishments and bleacheries for drying yarns and textiles, in the paper industries for drying wood pulp, and in the sugar and starch industries for drying the respective substances.

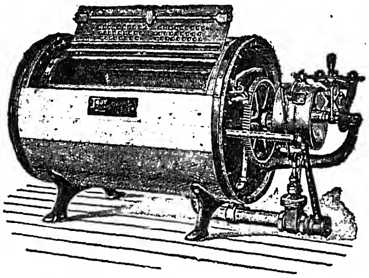


FIG. 194. WASHING MACHINE FOR FILTER CLOTHS.

The centrifugals are, according to local conditions, either belt driven or direct connected to electric motors. Both of these types are built either with under drive or upper drive.

On account of the high speed at which these machines are operating (900–1,200 revolutions per minute, according to size, *i. e.*, an average surface speed of 10,500 feet per minute) great strength and careful construction is an absolute necessity; as grave accidents

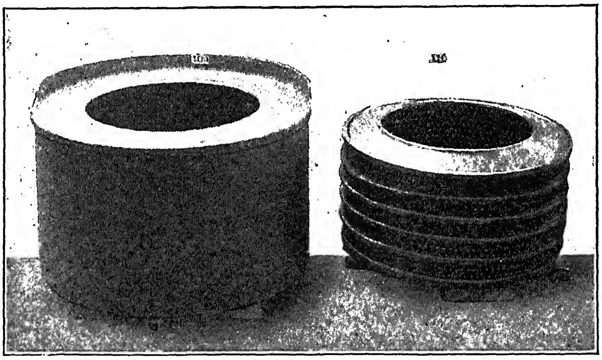


FIG. 195. CENTRIFUGAL BASKET AND DRUM.

might occur with a machine not properly built, centrifugals should never be bought from irresponsible concerns.

On the basket itself depends much of the centrifugals strength. Whenever the materials to be treated permit it, the baskets should be made of heavy hammered copper and bound by steel bands (as shown in Fig. 195, in which basket and drum is illustrated). This absolutely prevents them from bulging when running at a high rate of speed. In well constructed machines the copper bottoms of the

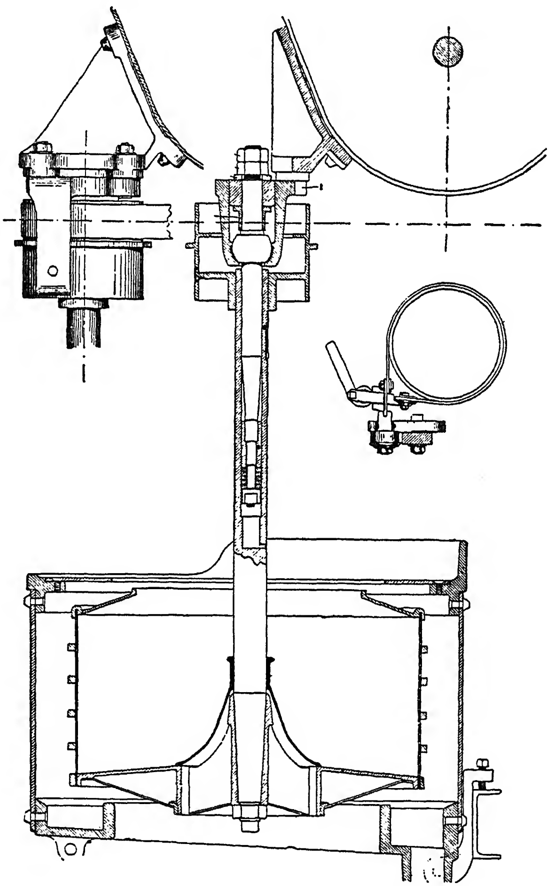


FIG. 196. BELT DRIVEN CENTRIFUGAL.

basket are reinforced by stout iron flanges. The perforations are first punched out, then countersunk by hand, so as to insure a perfectly smooth inner surface.

According to the material to be treated, the interior of the centrifugals is made of copper, steel, wrought iron, bronze, or brass.

The construction shown in Fig. 196 is built by the American Tool and Machine Co., Boston, Mass.

A belt-driven centrifugal (upper drive) and a ten-inch centrifugal for laboratory or experimental use, both built by the above company, are shown in Figs. 196 and 197 respectively. The large

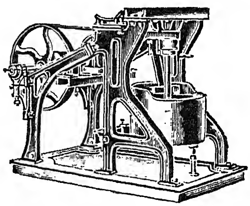


FIG. 197. 10-INCH CENTRIFUGAL.

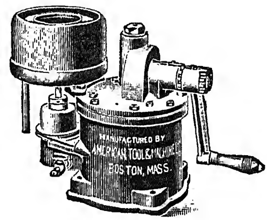


FIG. 198. 5-INCH HAND CENTRIFUGAL.

type is built in three sizes, viz.: 30 inches, 36 inches and 40 inches diameter.

They also build a five-inch hand centrifugal for laboratory testing purposes, as shown in Fig. 198.

It has to be borne in mind that the charge in the basket has to be uniformly distributed before starting the operation.

Other Filtering Appliances. For filtering thick masses vacuum filters are used, the vacuum being produced by means of a steam jet blower for a vacuum pump. For the handling of acids these apparatuses are made of lead or clay. Fig. 199 shows the application of a Koerting steam jet exhauster for assisting filtration.

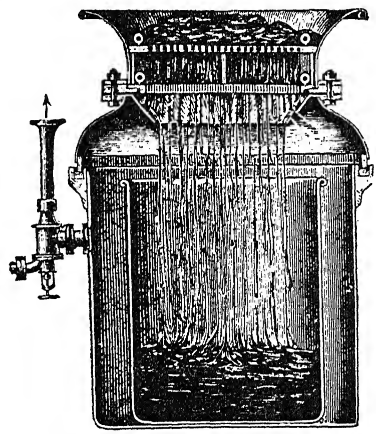


FIG. 199. VACUUM FILTER.

M. Garros recommends asbestos porcelain as filtering mass for strong acids. This material is prepared by grinding asbestos to a fine powder and washing the latter first with muriatic acid and then with pure water. The plastic mass so obtained is burned at about 1600° C., and shows after cooling such fine pores that it can be used successfully as filtering material. Another method of separating solids and liquids is the application of sand and other filters. For this purpose basins are built in which layers of pebble, gravel and

sand are provided, the latter being supported by perforated plates. The water to be filtered enters on top, flows to the three layers and finally reaches, in a pure state, the pipe line provided below the per-

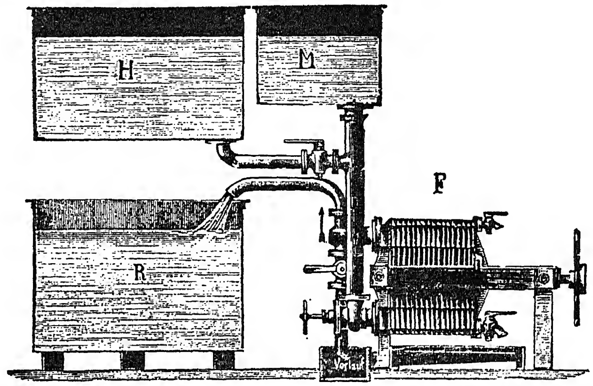


FIG. 200. FILTERING DEVICE.

forated plates. The operation of these filters is rather slow, gravity being the only active force. If a quicker method is desired, pressure has to be applied, as for instance, in the Jewell filters.

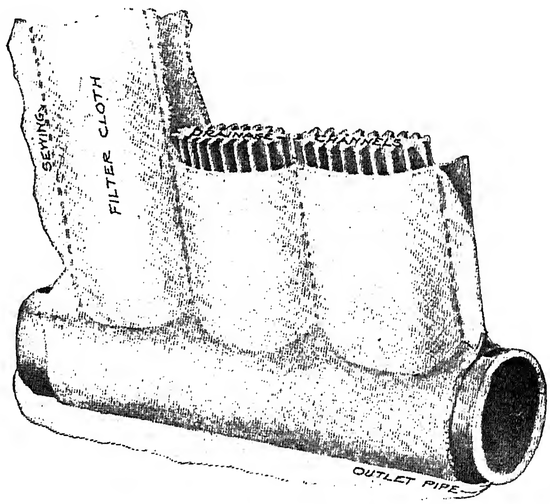


FIG. 201. BLAISDELL FILTER.

If the water is only cloudy and its filtration meets with great difficulties the following device is to be recommended (Fig. 200).

The reservoir H contains the water to be filtered; tank M contains

a thin pulp of cellulose or fibrous asbestos with water. F is the filtering apparatus proper and the purified water runs off into R. F is built like a filter press and contains a number of chambers, the walls being formed by metallic sieves.

At first the thin pulp or paste is passed (from M) into the filter

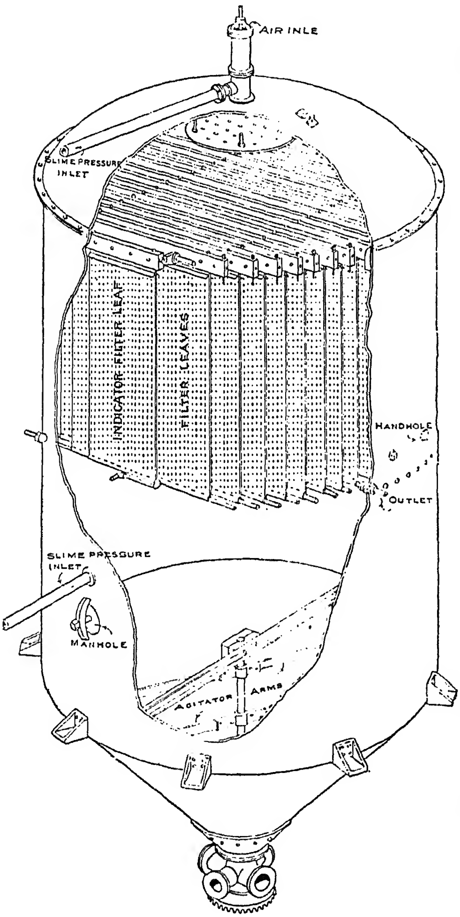


FIG. 202. BLAISDELL FILTER.

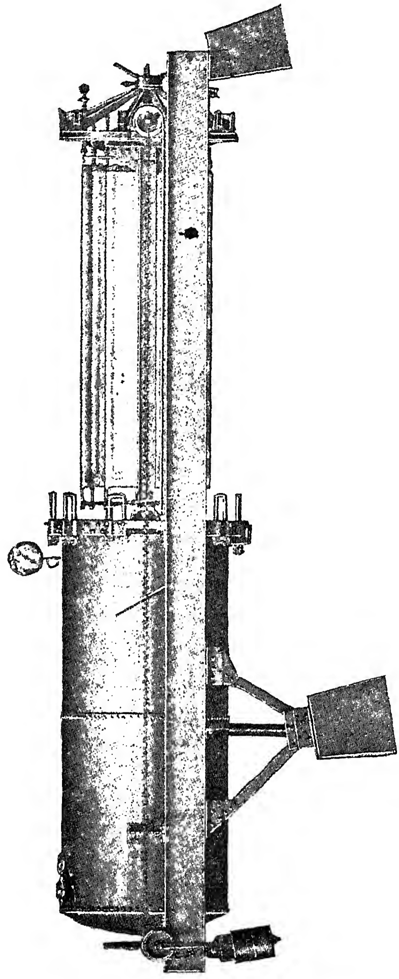


FIG. 203. KELLY FILTER.

F, where it is uniformly divided. The arrangement is somewhat similar to the three-chamber press mentioned above. The water from H is then allowed to run through this filtering mass and flows

into tank *R*. When the filtering mass becomes inactive, it has to be removed and washed, before being put to use again.

For filtering slimes the Blaisdell pressure filter can be used. This filter, which is illustrated in Figs. 201 and 202, contains a series of filter leaves, depending in number and size upon the capacity desired, a pressure cylinder and pumps for vacuum, slimes, water and solution, with pipes and valves.

With a pressure of 25 to 50 pounds per square inch in the pressure cylinder, the clear water or solution is rapidly forced into the interior of the filter leaves and out through the discharge pipe to the water or solution tanks, the slime remaining as a cake on the outside of the filter leaves. This process is continuous and is carried on without interrupting the flow of slime to the pressure cylinder. As soon as a cake of sufficient thickness is formed, clear water, under a greater pressure than exists within the cylinder, is admitted to the interior of the leaves in groups. This excess of pressure causes the cake on that particular group of leaves to fall through the slime to the bottom of the cylinder. The thickened material accumulating on the bottom of the cylinder is discharged from time to time.

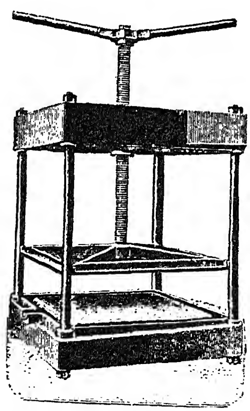


FIG. 204. SCREW PRESS.

The Kelly filter, shown in Fig. 203, consists of a tank in which a carriage runs on tracks carrying the filters. Whenever the filters are heavily charged with separated solid materials, and it is desired to remove the collected solid material from the sides of the filter frames, the carriage is run out of the tank onto an exterior trackway.

The construction of the Butters filter is based upon the same principle.

Presses. Presses are mainly used in the chemical industries for separating solids from liquids.

The simplest type which can be used for this purpose is the screw press (Fig. 204). The material to be dried is filled into bags or wrapped up in cloths and then put into the press. The various bags, etc., are separated from each other by means of metallic or wooden plates.

In the manufacture of smokeless powder the screw press shown in

Fig. 205, which is built by Werner and Pfleiderer, Saginaw, Mich., is extensively used. These presses are strongly built and are constructed so as to require not more power than hydraulic presses of the same capacity. They are very simple and can be handled with

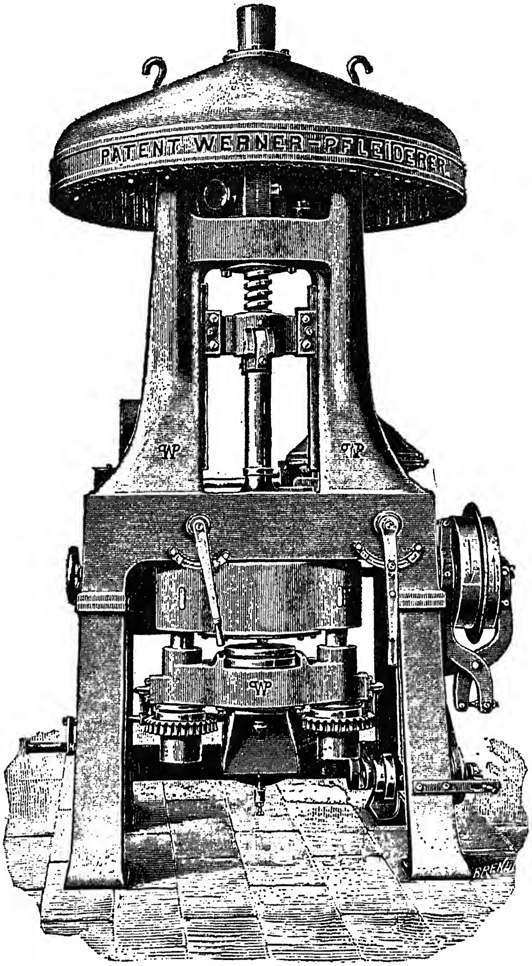
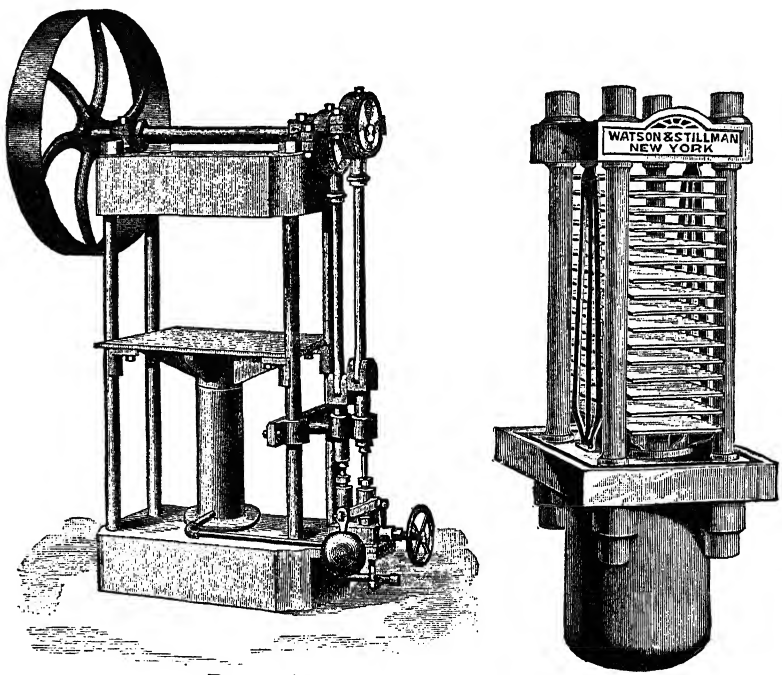


FIG. 205. SCREW PRESS.

perfect ease and safety. They are driven by a special reversing apparatus, provision being made to prevent them from being started in the wrong direction. They are started by moving a hand lever and are brought to a full stop automatically through an arrangement which stops the press when the piston has traveled to the prescribed

limit, either at the top or bottom. When in the highest position, the piston is swung backwards on a hinge, a suitable catch making it impossible to start the press from this position, but it is necessary that it be swung forward in place again, before the press can be started, thus preventing the numerous breaks which occur so often, when the operator forgets to put the piston in the proper working position. These presses have two speeds, fast and slow, in both directions.

For chemical work the hydraulic presses, Fig. 206, are of greatest importance, since their requirements as to power and attendance are



FIGS. 206, 207. HYDRAULIC PRESS.

small. The construction of the hydraulic presses is based upon the principle of the uniformity of pressure in liquids contained in closed vessels. The press consists of two separate parts—the press proper and the press pump. The press pump is a plunger pump provided with automatic relief set to a certain pressure, which naturally varies according to the nature of the material to be pressed.

The pressure produced by the press pump is transmitted from the liquid of the pump (water, glycerine or a mixture of both) to the

liquid in the cylinder of the press, whereby the same pressure is exerted upon the unit of area of the piston of the press as upon the unit of area of the piston of the pump.

The material to be pressed is handled in the same manner as with a screw press. If the pressing is to be performed at a high temperature, the plates separating the layers (cakes) have to be heated by steam. One press pump is sufficient for several presses.

Fig. 207 shows a press arranged with flat iron plates to which are to be attached hair cloth mats both top and bottom, and the material to be pressed placed between the mats in bags or cloths. The plates are guided in their movement both up and down, and when press ram is lowered each plate rests upon its own support on the side frames, pins being screwed in the plates for this purpose. A gutter surrounds the press for the collection of the oil. The use of plates allows about double the amount of material to be pressed that could be placed in a box press.

For some materials corrugated steel plates, which do not require matting, are much preferable.

Separation by Crystallization. For separating a dissolved salt from its solvent or from a mixed solution, various methods can be used. If the substances have the property of being precipitated by concentration, the solutions are evaporated and the separating crystals are continuously removed.

There are cases (Glauber Salt, etc.) where no direct precipitate is obtained during evaporation, but where it is necessary to cool the solution. The solid substances are then allowed to separate by crystallization in suitable vessels.

For effecting a uniform crystallization throughout the liquor, hooks made of steel or copper wire are suspended into the same, by means of which the crystals can be easily lifted out of the liquor.

If no hooks are used, the crystals formed fall to the bottom and the mother-lye has then to be syphoned off. If crystals deposit on the walls of the vessel they can be knocked off and removed by means of perforated spoons. Or, perforated pots are put into the vessel and the mother-lyc entering the pots is syphoned off.

Separation by Extraction is used for separating the soluble components from a partly soluble substance. The high pressure frequently applied during extraction is produced by either steam or compressed air, depending upon the nature of the material to be treated.

The extractor generally used for dyewood, tanbark, etc., is a vertical cylinder, provided with a charging and discharging opening, water and steam inlet and solution outlet. The armature consists of a manometer, thermometer and two test cocks.

If several of these apparatuses are connected to a battery, the connection is made in such a manner (Fig. 208) that the final solution

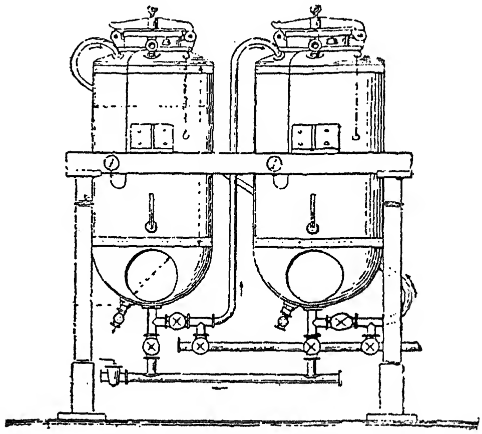


FIG. 208. EXTRACTOR.

of the first apparatus is utilized for eluting the fresh charge of the second apparatus, whereby the concentration of the solutions is increased. The apparatus to be discharged first, gets the fresh water, while the more concentrated solution is taken from the apparatus charged with fresh material.

An apparatus for extracting at high temperature and ordinary pressure fats, oils, rosins, etc., by using benzine, bisulphide of carbon, alcohol, etc., as solvents, is built by Josef Merz in Bruenn (Austria).

The vessel C (Fig. 209) contains at the bottom a steam coil Q, and above it a reservoir L, which is charged through the manhole d with the material to be extracted. From the reservoir V, which is combined with the cooler R, the solvent is allowed to flow into L. As soon as the level of the solvent exceeds the height of syphon y, it is drawn into C. In C the solution is evaporated, the vapors rise along the wall of the reservoir L, heating its content and finally arrive at coil S, where they are condensed. The warm liquid "rains" back into L and after rising to the height of the syphon, again goes into C.

This automatic circulation is interrupted, when a sample taken at *M* shows that the extraction is finished. The cooling water in *S* is stopped, the vapors of the solution flowing from *L* into *C* travel to

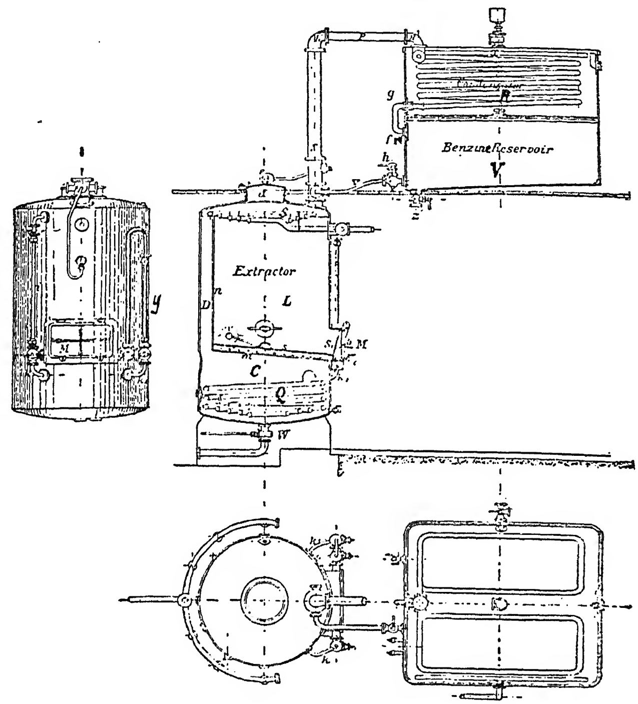


FIG. 209. EXTRACTION APPARATUS.

cooler *R* and are collected as liquid in reservoir *V*. The last traces of the solvent are removed from the extract and the spent material by means of direct steam.

The extract is discharged through *W* and the extractor *L* at *M*. This apparatus permits intermittent and continuous extraction. In the latter case the flow of the fat-solution is so regulated that the level of the liquid in *L* is kept constant by the evaporated and regenerated solvent.

This universal extractor affords perfect safety against ignition and explosion, insuring a minimum consumption of the solvent, simple and economical operation and absence of odors.

A twin apparatus for extracting essential oils is shown in Fig. 210. It consists of two stills which can be heated by leading steam into the "false bottom" or by direct steam led into the interior of the appa-

ratus. The solid substances to be treated in the extraction apparatus rest upon a perforated plate.

After charging the apparatus with the solid substances and the extracting liquid, the steam valve is opened, whereby the extracting liquid is vaporized. This vapor travels through the substance, rises upward along the dissolved components and enters the cooler.

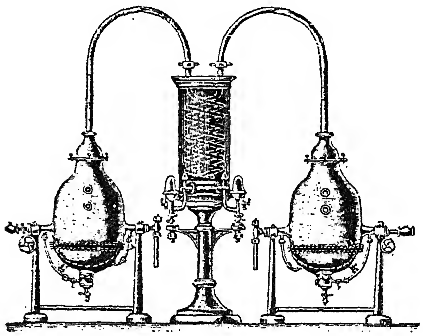


FIG. 210. TWIN EXTRACTOR.

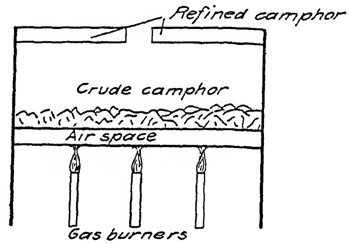


FIG. 211. REFINING CAMPHOR.

When leaving the cooler it is tested as to its "extract" contents, and recharged until it shows the concentration required.

Separation by Sublimation. This process, in which gaseous distillates are directly solidified without passing through the liquid stage, is employed in the case of iodine, salammoniac and camphor. Fig. 211 shows a simple apparatus for subliming camphor. The refined camphor forms a solid cake at the top of the vessel, while the impurities remain as a residue on the bottom.

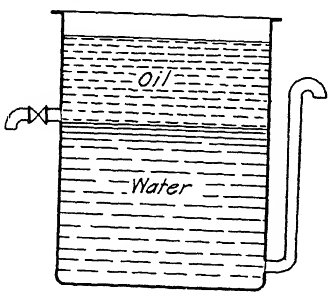


FIG. 212. SEPARATION OF OIL FROM WATER.

Separation by Settling and Freezing. Liquids of different specific gravity which do not mix can be separated by allowing the heavier liquid to settle. The apparatus (Fig. 212) has near the bottom an opening, to which an S-shaped overflow pipe is connected. If a layer of oil is floating upon the water, only the water will flow through this pipe. If the oil is to be collected, the water is let off until its surface is on the same level as the cock at the left side. Then the oil is allowed to run off through the cock.

Sometimes liquids are separated by cooling and removing the frozen part from the liquid (Lunge's monohydrate process).

Separation by Dissolving, Eluting and Decanting. The products obtained by chemical reactions frequently consist of several substances of various composition, and thence, it is necessary to treat the products of reaction further for separating their components. This treatment depends entirely upon the property of the mass to be handled; if the latter is perfectly soluble, it is treated with a liquid until it is completely dissolved, and then the individual components of the solution so obtained are separated by various methods. If the product of reaction is only partly soluble, a solution is also made in a suitable solvent and the solution obtained is separated from the insoluble solid components by operations, such as filtering, etc. According to the solubility of the mass, various methods are used for effecting a complete recovery of the soluble components.

Wherever water of ordinary temperature can be used, this naturally will be done, but in cases where cold water is not effective, hot water or steam has to be employed. This operation can be performed in open or closed vessels, and the decision in this selection will depend on the fact whether high steam pressure is required, and if during the solution detrimental vapors are generated.

In many cases, in place of water, a dilute solution of the substance to be recovered will be used, as thereby the same is gradually concentrated, which means a considerable saving of coal in the evaporation, eventually to be performed for final concentration.

For increasing the velocity of the dissolving process and for obtaining solutions nearer to the point of saturation in open and closed vessels, stirrers are used similar to those used in mixing machines.

Vertical stirrers are to be preferred to horizontal ones, as in the latter the stuffing boxes of the shaft are exposed to a considerable wear, partly because they are always in the solution, coming continuously in frictional contact with the solid particles contained in same, and partly as the entire pressure of the stirrer or agitator against the mass, and the weight of the stirrer has to be carried by them. A further disadvantage of the horizontal construction is the higher cost of repairs.

In vertical stirrers only one stuffing box is required, which is provided on the top, and which, in closed vessels, has to be only steam tight, as the solution does not come up so far.

The residuum obtained by the separation of the insoluble solid substances from the liquid (by simple filtering, centrifugals, etc.) contains generally so many liquid particles still enclosed, that the recovery of same is of advantage, and in some cases even absolutely necessary. Hence in filter presses the residuum is washed by means of water, diluted solutions of the respective liquid or by means of other liquids, either until the residuum is of the purity required or as long as the wash water obtained allows an economical using over of same. Similar conditions prevail with material obtained from centrifugals.

If only the solid components are to be recovered, the wash waters obtained in the various stages are not separated; however, they are separated according to the specific gravity, if the solutions are to be worked up. This is done most conveniently by connecting the outlets of the respective filtering apparatus with a main pipe line, and by leading the liquids therefrom, according to their specific gravity,

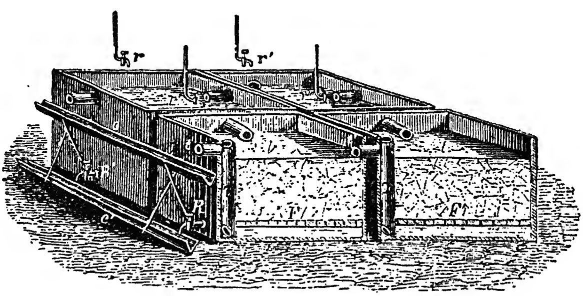


FIG. 213. SHANKS APPARATUS.

through various pipe lines to the storage vessels. The liquids of sufficient strength can now be worked up directly and the thinner liquids can be used as eluting liquor for enrichment. The proper selection of the eluting or washing arrangement and the limit to which these operations are carried on, is frequently of great importance for economy.

The materials used in the construction of these apparatuses depend upon the property of the solution; the construction and the operation of these apparatuses, again, depend upon the materials.

A dissolving apparatus which is used to some extent in the soda industries (Leblanc system) is the apparatus of Shanks, Fig. 213, which is based upon the fact that the specific gravity of a solution

increases with its concentration, and that a column of a weak solution is kept in equilibrium by a lower column of a stronger solution. The tanks are arranged on the same level; water, passing through the tanks, is dissolving or eluting the material and is getting constantly more and more concentrated. The column of the liquid is decreasing in height from tank to tank, from the first which contains pure water, to the last, from which the concentrated solution is running off. The tanks are provided with false bottoms, made of perforated sheet iron. A pipe *T*, open at both ends, and having a diagonal section at the bottom is reaching from the bottom of each tank to the surface. Each of these pipes *T* is provided at the top with a short horizontal pipe *t*, connecting one tank with the other. By means of the water pipes *r* each tank can be filled with water. Cocks *R* for discharging the solution are provided below the false bottom. For crude soda ash four washings are generally sufficient.

A very simple and effective apparatus for rapidly dissolving, lixiviating, mixing and agitating such materials as chloride of lime, salts, sulphate of alumina, sulphate of barium, etc., at an exceedingly small expense of power, without the use of steam is the machine shown in Fig. 214, which is built by Werner and Pfleiderer, Saginaw, Mich. In this apparatus the material to be treated is drawn with the liquid by means of a tangential wheel into the interior of the same and is thrown out sideways with great force. As the material passes through the interior of the tangential wheel, up the wall of the egg-shaped trough, and in the axis of the trough to the tangential wheel, there are many changes of the direction of motion, which result in an energetic treatment of the material.

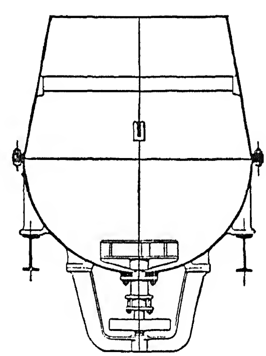


FIG. 214. DISSOLVING APPARATUS.

A decantation tank as built by the Allis Chalmers Co., Milwaukee, Wis., is shown in Fig. 215. It is of conical bottom shape and furnished with piping and centrifugal pump so that, after settlement is effected and the supernatant solution is decanted, additional solution or wash water may be introduced and thoroughly mixed with the solid material through the medium of agitation, employing a centrifugal pump, after which subsidence is permitted, followed by decantation.

Digesters. If liquids are to be heated to a temperature above their boiling point, *i. e.*, if the work is carried out under pressure, especially constructed apparatuses are used, which are called digesters. Digesters, like many apparatuses used in chemical engineering,

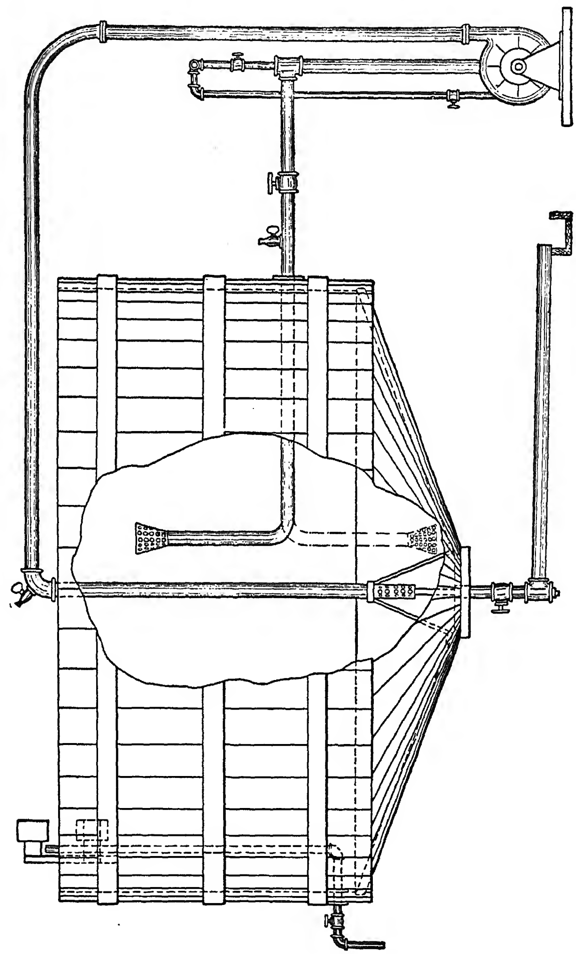


FIG. 215. DECANTATION TANK.

are generally built to order, according to the designs of the chemical engineer of the firm which places the order.

These are cylindrical or spherical vessels, which are, corresponding to the pressure generated, of heavy construction and generally provided with a removable cover on top, which allows the cleaning and inspection of the interior space of the apparatus.

The digesters are further provided with charging openings, safety

·es, thermometer tube and manometer and are heated by means steam or direct firing. The latter either heats the walls direct, if a double wall is used, the heat transmitting substance, water, or alloys (Fig. 216).

: is frequently necessary to use digesters, which are provided ı stirrers.

.s regards the materials to be used in the construction of digesters,

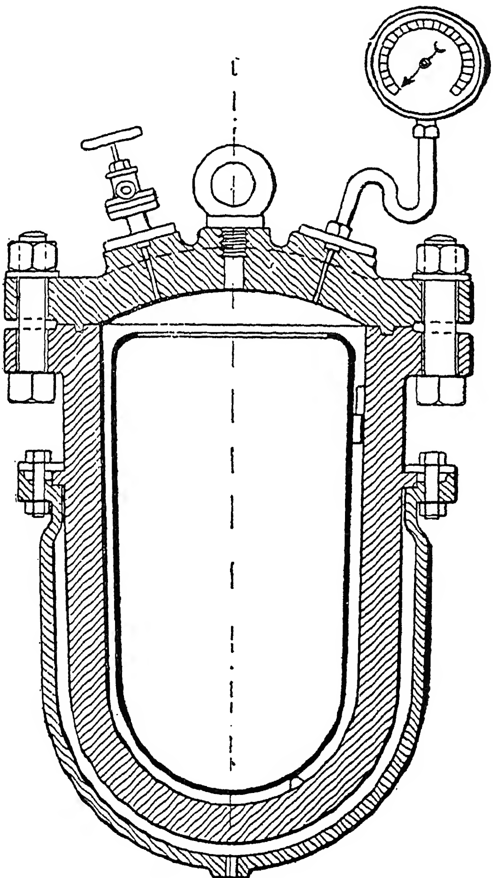


FIG. 216. DIGESTER.

s obvious that they have to be selected according to the properties the substance to be treated in the apparatus; digesters made of t iron are most frequently used; if necessary they are lined with d or provided with an enameled lining. Wrought iron and copper only rarely used.

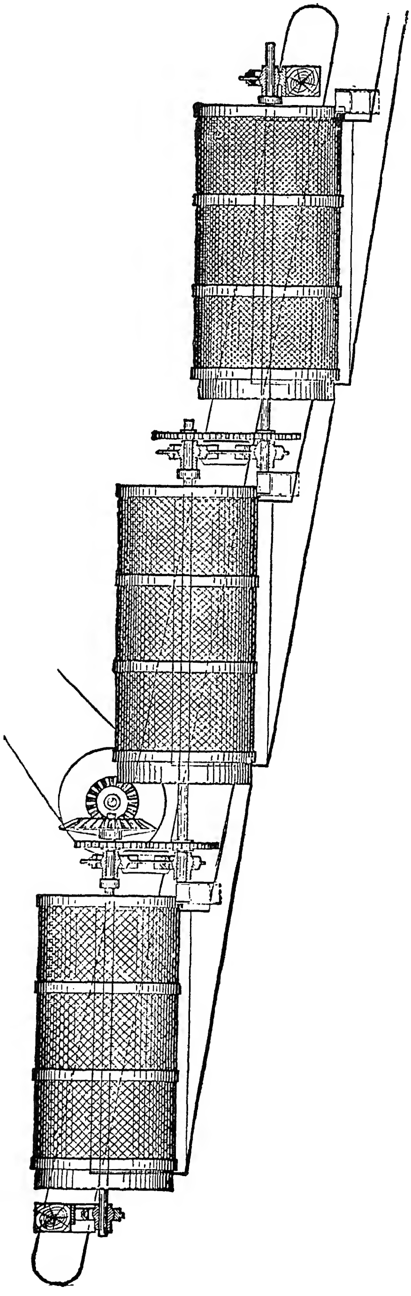


FIG. 217. SCREEN.

These apparatuses, which are built in various sizes, require, on account of the danger of operation, special care in the making. Hence a special brand of cast iron is used for preparing the castings. The bolts are made out of rivet steel. Before being used these apparatuses are being tested at a pressure of 100 to 200 atmospheres, depending on the pressure which they will have to stand in the regular operation.

The digester built by H. W. Dopp Co., Buffalo, N. Y., consists of a steam-jacketed kettle provided with a strong domed and ribbed cover clamped, with steam-tight packing, to the kettle by means of eight cam clamps. The cover can readily be unclamped and thrown back on a loose hinge by means of a light tackle.

Separating Solids from Solids. The separation of solids from solids is performed by various appliances, according to the size or according to the specific gravity of the materials contained in the mixture.

Screens. The separation of substances according to their size ("sizing") is a matter of great importance in metallurgy and is generally performed by means of screens, Fig. 217, made of perforated metal or

wire cloth. In concentrating works three, four or more screens are frequently combined to one unit. The first screen separates out all pieces too large for the ore treatment processes, so that they may be returned to the crushing machinery. The remainder passes through the perforation of the first screen, and is conveyed to the second screen, which has finer perforation or meshes and is placed at a lower level, and so on through the set, each screen furnishing a product sized between the limits of the size of its own perforations and the perforations of the proceeding screens.

Inclined vibrating screens are also frequently used, the fineness of the separated product being dependent on the angle of inclination at which the screens are set.

Jigs. The oldest appliance for separating materials according to their specific gravity is the Hartz jig (Fig. 218). The essential features of this jig are: A two-compartment water tank, the compartments being connected together at the bottom of the tank; a horizontal sieve near the top of one compartment, and a plunger having an upward and downward movement produced by various devices, such as cranks, eccentrics, etc., in the other compartment. When ore properly crushed with its accompanying rock, earth, etc., is fed to the jig over the wire sieve, and both compartments are filled by a continuous flow of water and the plunger is set in motion, its downward stroke will force a quantity of water into the other compartment and upward through the wire sieve into the mixture of ore and gangue resting on it. The force of this upward flow of water through the mixture raises it off the wire sieve and for an instant holds it in suspension; the heavy ore or "concentrates" settles to the sieve, and the rock, earth, etc., are driven to the top, where they are freed from the jig by a current of water flowing over the wire sieve.

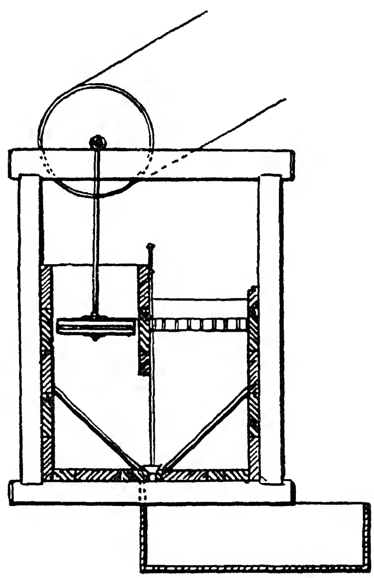
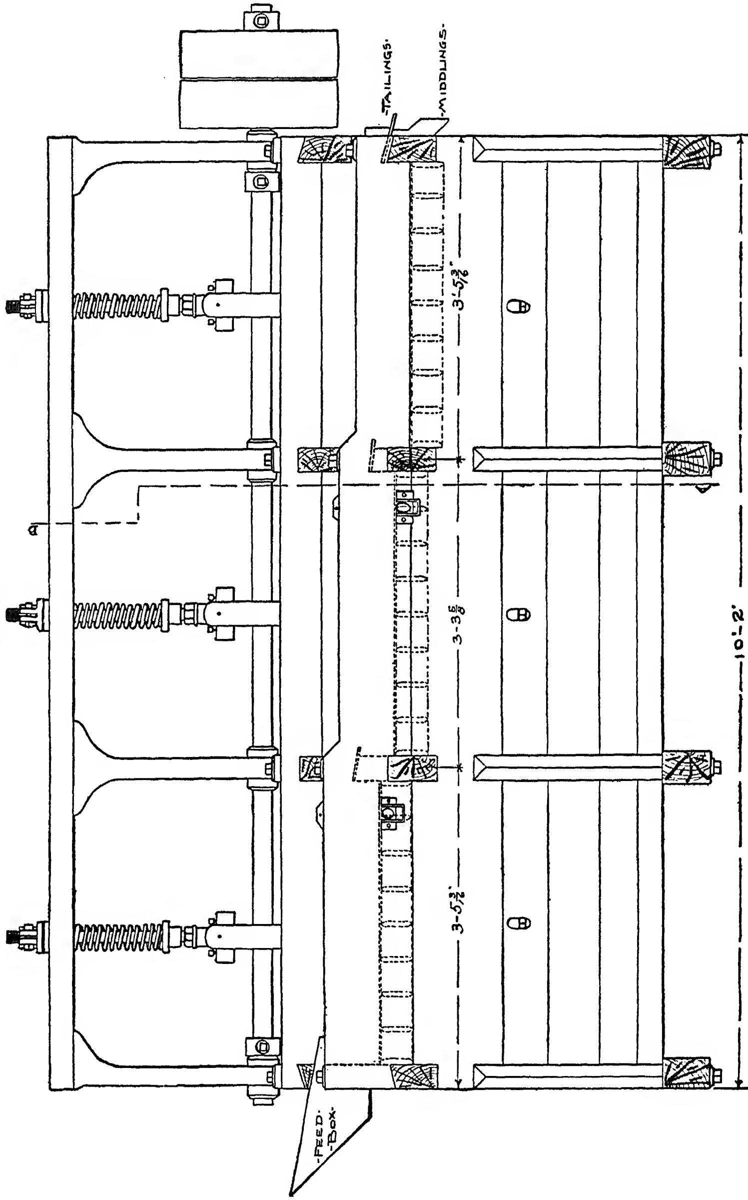


Fig. 218. Hartz Jig.

The fine concentrates go through the sieve into the tank or "hutch" of the jig, from whence they are removed through a hutch



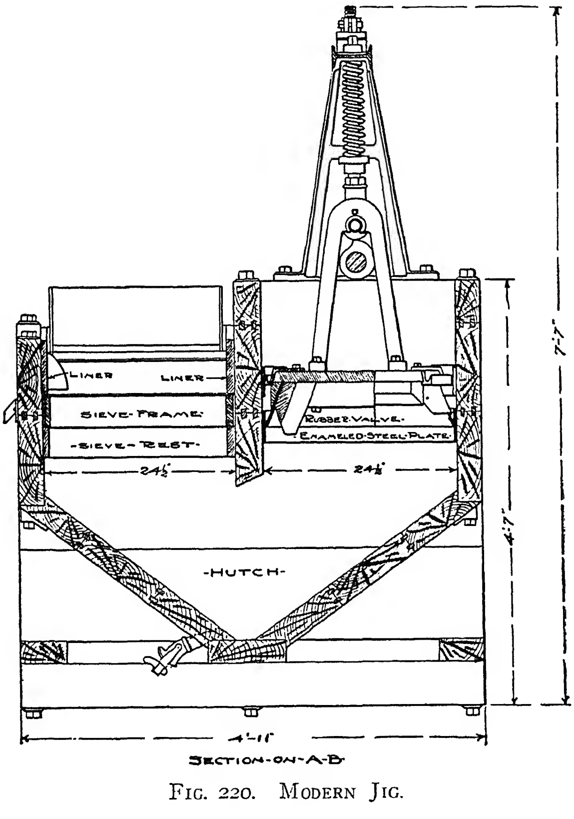
FRONT-ELEVATION.
FIG. 219. MODERN JIG.

cock. After a bed, varying in thickness from 1½ to 3 inches, of coarse concentrates has accumulated on the sieve, the accumulating

surplus is removed through a "side draw" or other types of ore bed draws.

The jigs are built with a varying number of compartments from one to six; they are placed one after the other in succeeding lower levels. The number of strokes of the plunger varies under different conditions, from 75 to 300 per minute. A modern jig is shown in Figs. 219 and 220; it operates as follows:

Let ore be fed to the jig, and the tank filled by a continuous



SECTION-ON-A-B

FIG. 220. MODERN JIG.

supply of water which just covers the plunger and the machine started in motion. As the cam revolves and the roller drops off its highest point, a quick downward stroke of the plunger is produced by the tension of the spring underneath the fixed I beam. The length of this stroke is adjusted by the nut above the beam which supports a rubber buffer on which the nut drops. The effect of this quick and positive downward drop is to force outward the

pieces of rubber belt on the sides of the plunger against pieces of enameled steel secured to the walls of the plunger compartment, and to deliver all the force of the stroke on the ore bed opposite, raising it off the wire sieve and leaving it in the desired condition of suspension in the water.

The length of stroke, excepting in unusual cases, varies from three eighths to three quarters of an inch only; hence, when the roller drops off the high point of the spiral cam it does not touch its inclined plane surface leading up to the high point again, until a large portion of the revolution of the shaft has been completed. This affords the period of absolute rest for the plunger, a positive requirement to a perfect jig, and which permits gravity alone to act on the ore and gangue. When again the roller strikes this inclined plane surface of the cam, its upward stroke to its highest point is comparatively slow, the flap valves on its sides instantly yield and allow the water to flow past them to fill the vacuum below, and all tendency to produce the dreaded suction in the ore bed is completely stopped.

Coal Washeries. Washed coal is so named from its hydraulic separation from impurities, such as slate, sulphur, clay, etc. The specific gravity of coal is about 1.28, while that of the impurities is much higher. It is the usually accepted practice in washing to save as coal, material having a specific gravity of 1.35 and less, and to reject all material of a specific gravity over 1.45, because it does not contain enough coal to be worth saving.

Complete coal washing requires three separate processes:

1. The separation of the coal.
2. The actual washing or mechanical separation from the impurities.
3. The recovery of the washed coal and refuse from the water, and the disposition of these products in suitable bins for subsequent removal.

To prepare the coal it is crushed to nut and screened into four or five sizes to facilitate the washing and sale of the clean product; or in a plant exclusively for coking, reduction of all the coal to a size of $\frac{1}{2}$ inch or less.

The scientific washing of coal has reduced itself to the use of the jig, of which there are two general types:

1. Where the water is caused to pulsate through the material to be washed by the action of a plunger.

2. Where the material is carried in a box with perforated bottom, which is moved up and down in a tank of water.

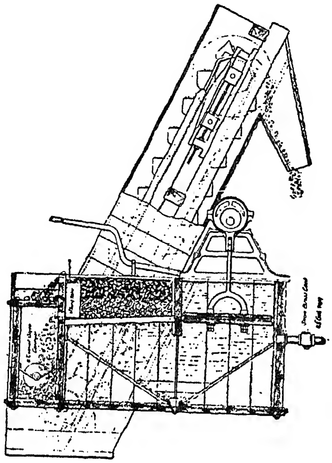


FIG. 221. LINK-BELT LUHRIG JIG.

The Link-Belt "Luhrig" Jig (Figs. 221 and 222) belongs to the first class and is the best known and most extensively used in this country and abroad. By the Luhrig process, coal is accurately

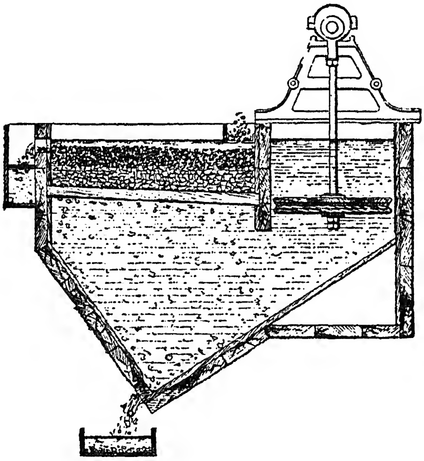


FIG. 222. LINK-BELT LUHRIG JIG.

graded to size, two styles of jigs, as shown, being used: one adapted to nut coal and the other to the finer sizes.

The Link-Belt "Stewart" Jig, Fig. 223, gives good results with the coarser sizes of coal, but because of the size of screen and violence of agitation necessary to proper separation of the coarser refuse from the coal, it is not suited to the finer materials.

Concentrating Table. A concentrating appliance which is widely used is the concentrating table. Fig. 224 shows the Overstrom concentrator, which is manufactured by Allis Chalmers Co. This machine is a diagonal table, with the table top placed diagonal to the line of reciprocation, for the reason that in concentrating min-

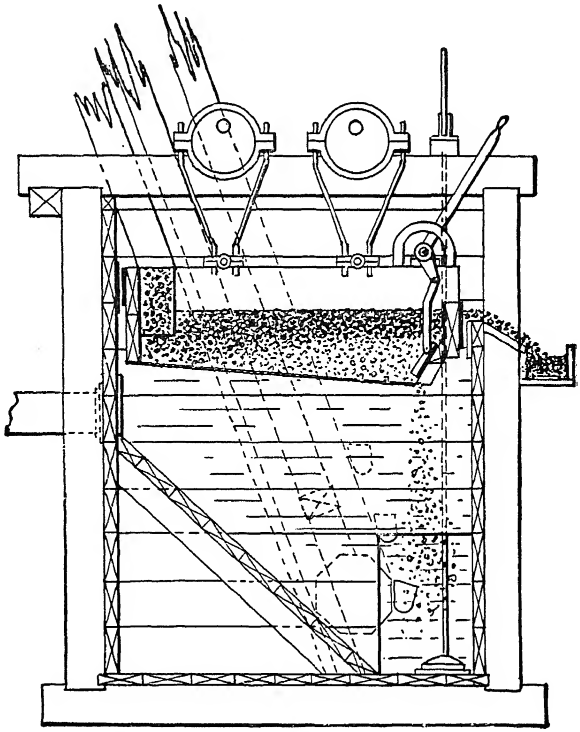


FIG. 223. LINK-BELT STEWART JIG.

eral particles on a table three forces are employed: Gravity, reciprocating motion, flow of wash water.

Gravity acts on the mineral particles, forcing them downward, the heavier particles occupying the lower stratum.

The reciprocating motion of the tables tends to bring the particles of ore forward in the direction of the line of reciprocation. This motion has a greater action on the particles of mineral, as they

are closer in proximity to the table surface, than on lighter gangue or silica, which remains on top of the mineral.

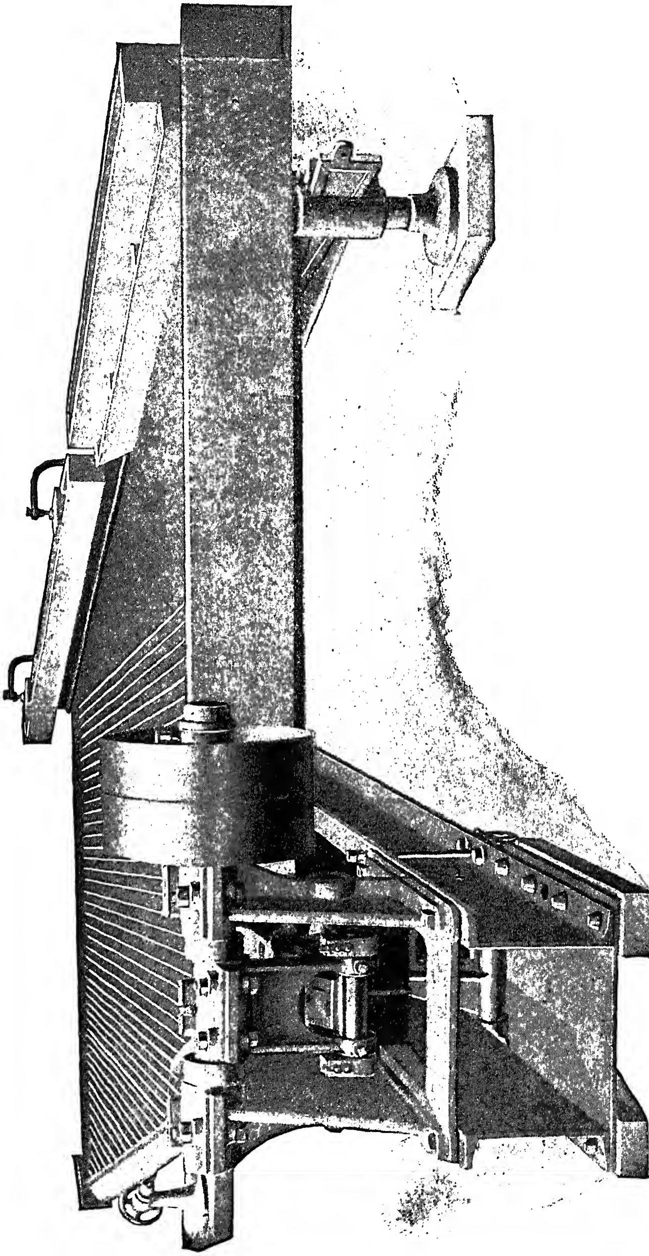


FIG. 224. OVERSTROM CONCENTRATOR.

The flow of wash water, transverse to the reciprocating motion, produces a greater movement of the gangue or silica than of the mineral particles, owing to the difference in specific gravity, and washes the particles of the lighter gangue a greater distance in a given time. As the gangue is on top of the mineral, it is acted upon more freely by the wash water, until a final separation takes place.

Of the three forces employed, gravity acts in a vertical line, while the reciprocating motion and the flow of wash water act in nearly transverse horizontal lines.

The resultant of the two horizontally acting forces is a line diagonal to both. Consequently the travel of material, both mineral particle and gangue, is in a diagonal direction. For these reasons this table is built diagonally to the reciprocating force and to the flow of wash water. The long feed box provided on the table distributes the feed evenly over a large surface, and as a result of the shaking, the box becomes an especially efficient sizer in itself.

Washing Sand. A separating apparatus, which is used for washing sand, is built by the Schutte and Koerting Co., Philadelphia, Pa.

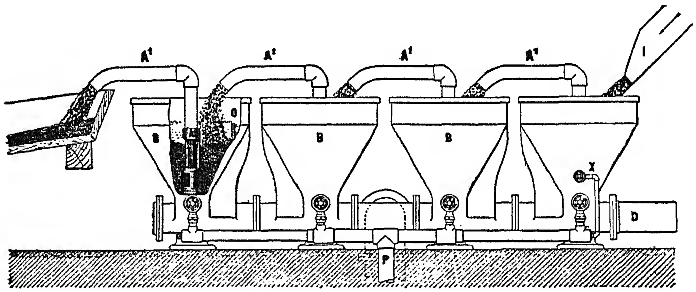


FIG. 225. APPARATUS FOR WASHING SAND.

Such a plant is illustrated in Fig. 225 and consists of a series of iron boxes *B* placed in one or more rows, or in a circle, and in each of the boxes is installed a water jet eductor *A*. In the first box, the sand, which is to be washed, is admitted at *I* and at the same time is stirred by means of a clean water jet at *X*. The sand eductor is operated by means of clean water taken from pressure pipe *P* and lifts the sand to the second box. As the sand or gravel is heavy it drops to the bottom of the box, while the water mixing with the dirt on account of violent stirring, rises and overflows

together at *O*. In this manner there is obtained a perfect cleansing of sand by the use of clean pressure water only, without the assistance of any mechanical means. Such plants are suitable and quite important for water works, as well as glass manufacturing industries, where sand must be free from clay or iron.

Movable arms are used to put in operation more or less boxes, according to the nature of material to be cleaned. For instance, in a plant of six boxes, a movable arm is placed in the third and sixth boxes, and then the sand may be run through all six or the plant may be operated in two rows, each using three boxes. It is desirable that the water should be as clean as possible, and the pressure at the eductor should be under a head of 30 to 40 feet, depending upon the material to be washed.

Magnetic Separation. Magnetic separation depends on the fact that some minerals are more strongly attracted by magnets than others. A widely used separator of this kind is the "Wetherill."

CHAPTER XII.

PURIFICATION OF GASES.

Separation of Gases from Solids. The removal of dust from gases is quite an important metallurgical and chemical problem, which can be solved in different ways. In all the processes used for this purpose, however, it is necessary to cool the gas before separation can be effected. In some cases a simple cooling is sufficient to remove the dust nearly completely. Such a gas-cooling apparatus is shown in Fig. 226. It consists of a sheet-iron channel

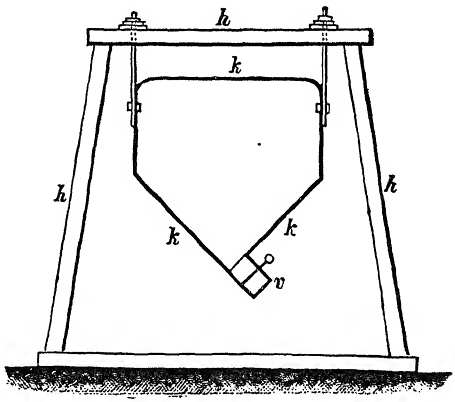


FIG. 226. COOLING APPARATUS.

K. The dust collects upon the bottom of same and is removed through openings *v* provided in certain distances.

Filtration is frequently employed for collecting dust, which is contained in gases in a finely divided state. In the manufacture of zinc oxide, for instance, the air containing the oxide is filtered through bags in which the solid particles are retained.

The air filter built by the Carrier Air Conditioning Co. is described in Chapter XIV.

A decrease of the velocity of the gas current also facilitates the separation. For this purpose the gases are led into chambers or channels before they are allowed to escape through the stack, as decrease of draft is not nearly as effective as frequent and con-

tinued contact with large surfaces; narrow channels are more advantageous than large chambers.

Another way of causing separation is the change of direction of the gas current, which is the more effective the cooler the gas. Zig-zag shaped channels are used for this purpose.

For removing the dust from blast furnace gas, wet processes are

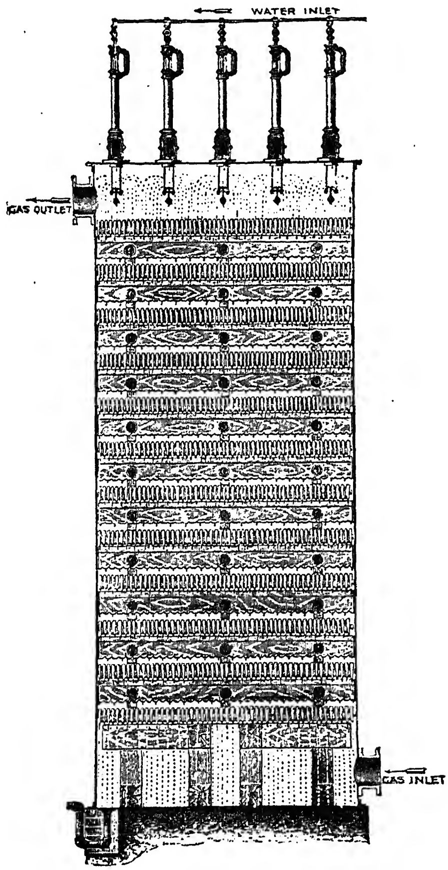


FIG. 227. ZSCHOCKE SCRUBBER.

almost exclusively used. In the Zschocke system the gas is washed in scrubbers, which are so constructed that they cannot be clogged up by the dust. Fig. 227 shows a sectional view of such a scrubber, Fig. 228 illustrates the arrangement of the scrubber filling. In the Buffalo system, built by the Buffalo Forge Co., the gas is exposed

to the action of a rapidly revolving fan, Fig. 229, into which water is injected, the removal of the dust being due to centrifugal force.

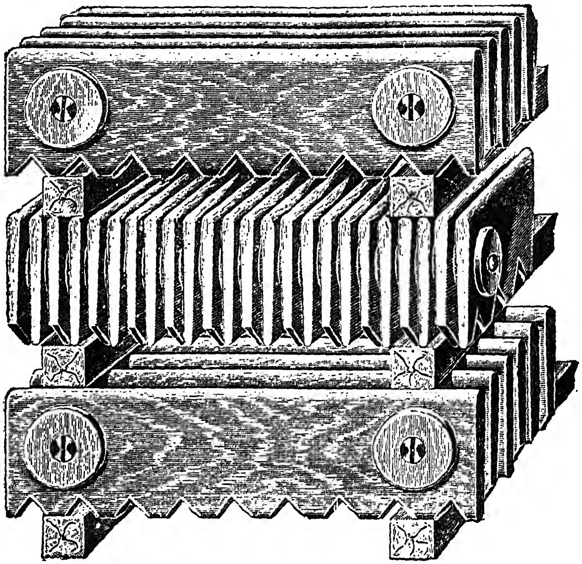


FIG. 228. SCRUBBER FILLING.

The dust particles are thrown against the water covered surface of the interior of the housing. This surface is kept covered with a water film by a spray which fills the interior of the fan at all times.

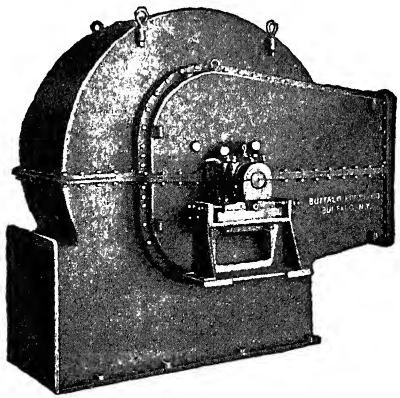


FIG. 229. BUFFALO GAS CLEANSING FAN.

An effective method for removing solids from gases is the application of a fine spray of water whereby the dust is precipitated.

Fig. 230 shows one of the spray nozzles as they are manufactured by the Schutte and Koerting Company, Philadelphia, Pa. They are made for various applications, according to the pressure of the liquids to be atomized; further, according to the diameter of the

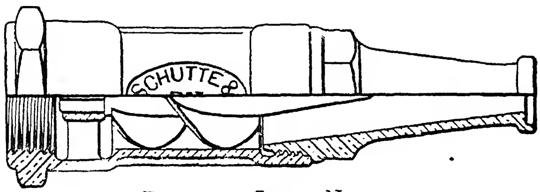


FIG. 230. SPRAY NOZZLE.

orifice and the form of the spray, any or all kinds of effects may be accomplished.

The working of these nozzles is clearly shown in Fig. 231, which illustrates the application of these instruments in sulphuric acid

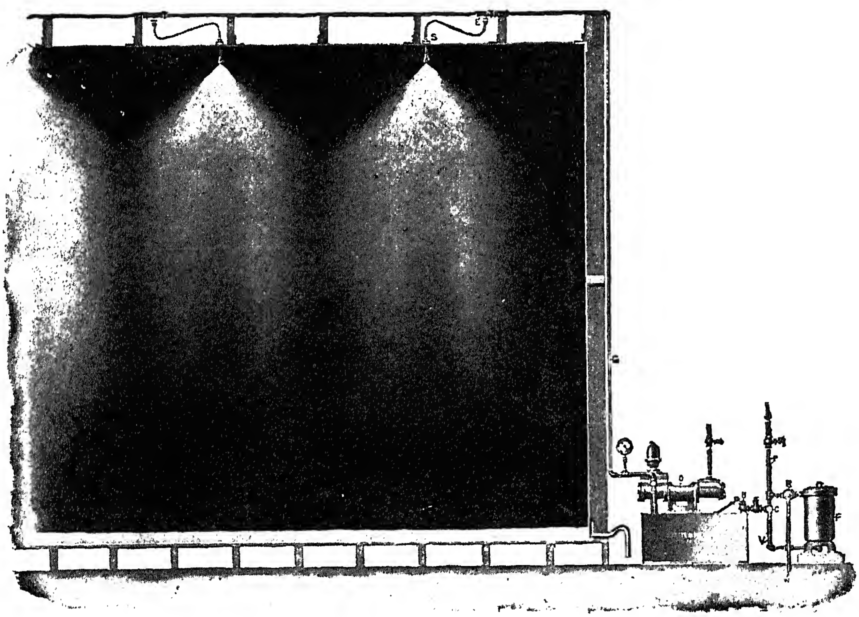


FIG. 231. APPLICATION OF SPRAY NOZZLE.

plants. In such plants the output is considerably increased, compared with the old system, where steam was injected in the acid chambers, for the reason that the steam condenses very slowly, especially during the hot season, thus reducing the output of the plant.

In the cut, which shows the arrangement of the Koerting glass or platinum spray nozzles, the water enters at *P,* passes through the filter *F,* and from there through the float valve *B* into the tank, from where the pump takes the water, forcing it under sixty pounds pressure to the nozzles installed on the top of the chamber. Each

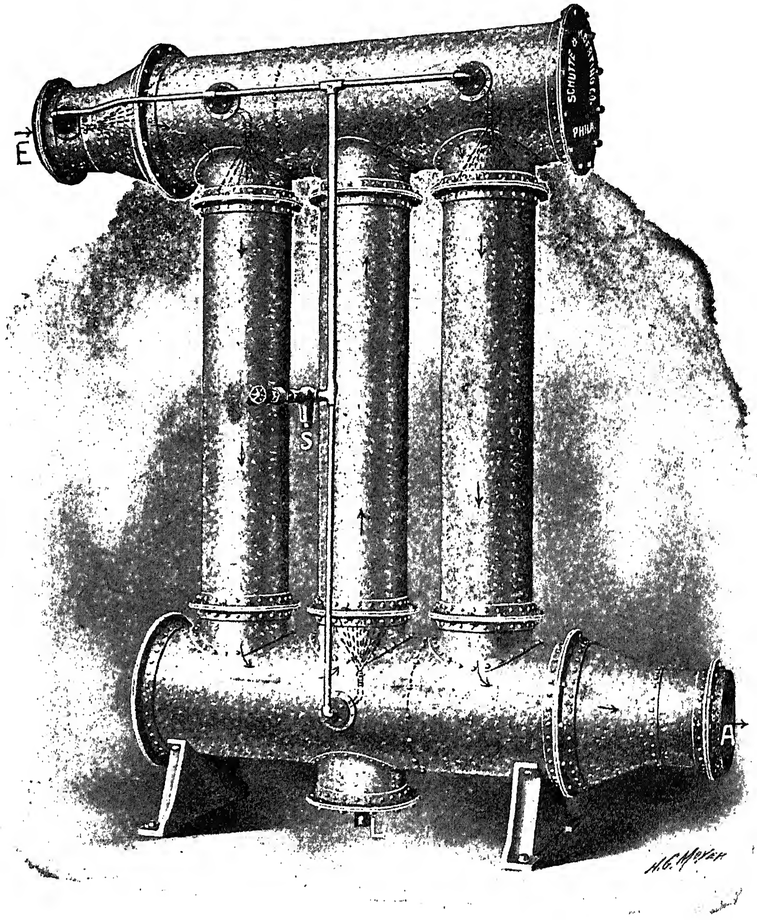


FIG. 232. REMOVING DUST BY MEANS OF SPRAY NOZZLE.

nozzle is protected by means of a separate strainer, which is necessary on account of the small openings.

The application of these nozzles for removing and precipitating dust is shown in Fig. 232. The air or gases enter at *E* and are discharged at *A* completely cleaned. The air is forced through the dust collector by jet ventilators or rotary fans. The precipitating

of the dust and vapors is done by means of nozzles. The pressure water for the nozzles is carried to the apparatus after it has passed the strainer *S*. The water is discharged through pipe *L*. These dust collectors have proven very satisfactory in various industries.

In connection with grinding installations, where dust is to be collected in a dry state, without the use of sieves, so called air separators are used.

In the separator of Mumfort and Moodie, shown in Fig. 233, a ventilator *E* is provided upon the vertical shaft E_2. The latter car-

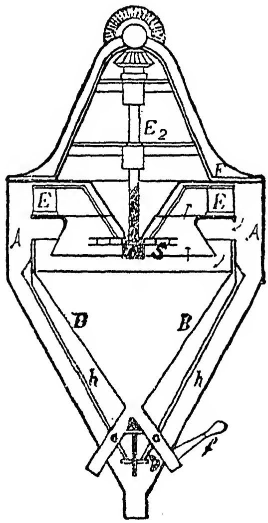


FIG. 233. SEPARATOR OF MUMFORT AND MOODIE.

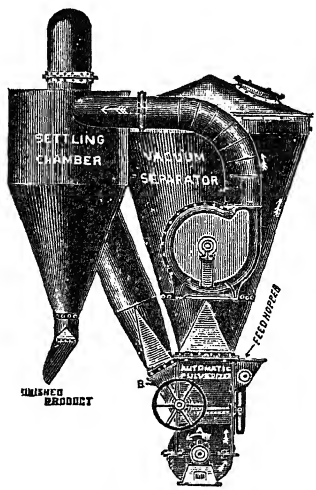


FIG. 234. VACUUM SEPARATOR.

ries also the distributing plate *S*, the object of which, as the name implies, is to distribute over its periphery the material to be separated. By a system of rings, disks and cones, the air drawn in by the ventilator is forced through the material which is constantly falling down in the shape of a bell. The air current carries the fine, dusty particles along and enters the ventilator, the mixture being thrown against the wall of the cylindrical tank *A*. The fine particles are carried to the bottom by the air current. The coarse parts not carried along by the air current fall into the interior cone *B* and may be retransported to the mill through pipe *a*, while the separated fine product falls into the space between housing *A* and cone *B*, and is removed from here by hand or screw conveyer.

A vacuum separator which is successfully used in connection with any form of grinding mill, the material being elevated and discharged into the hopper of the separator in the same manner as to a bolting reel, is shown in Fig. 234. In this apparatus, which is built by the Raymond Brothers Impact Pulverizer Co., Chicago, Ill., the material is fed automatically into the center of the tailing spout, above where the return air enters.

Separation of Gases from Liquids. If it is desired to separate gases from liquids in which they are absorbed, the process to be

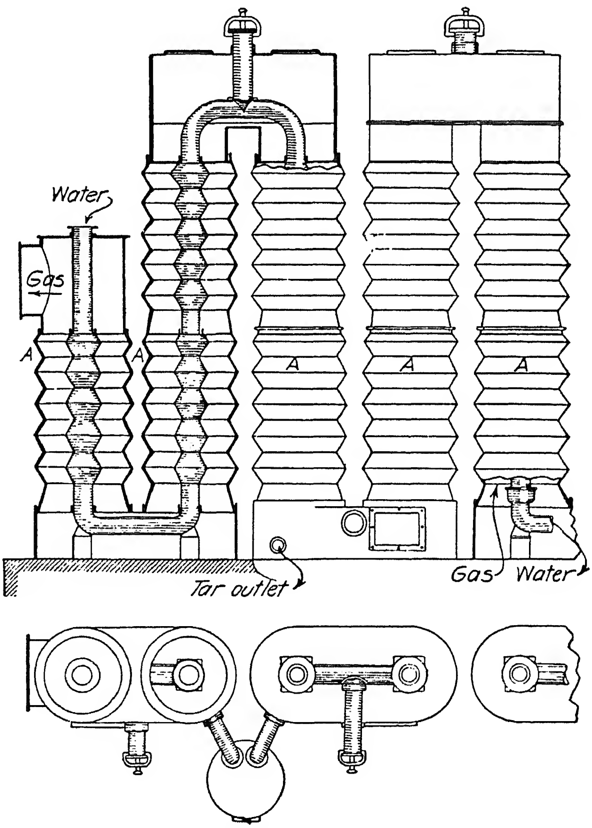


FIG. 235. MOHR'S COOLER.

applied will be different according to whether the gas liberated is to be used or wasted. In the former case a distilling apparatus with condensing cooler will have to be used, while in the latter case an evaporating apparatus can be applied. Gases that are absorbed

by liquids at high temperatures can be conveniently separated by cooling the liquid. An apparatus which is successfully used for this operation is Mohr's cooler, Fig. 235. It consists of zig-zag shape

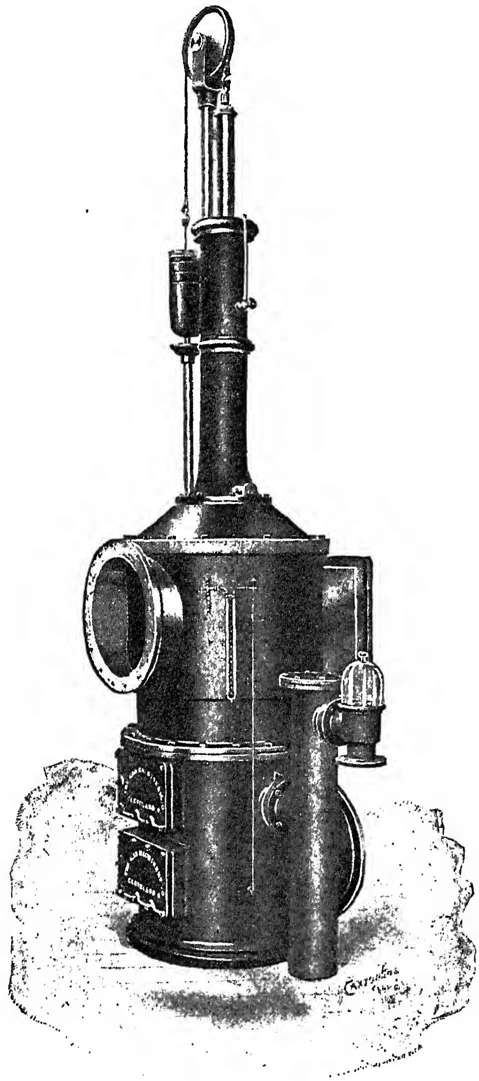


FIG. 236. TAR EXTRACTOR.

pipes, containing in the interior cooling pipes of the same shape. The outside pipes *A* are connected at the top and the bottom by

so-called connecting boxes; in the bottom boxes outlet openings are provided for the liquids separated.

The separation of gases and liquids is of considerable importance in the manufacture of illuminating gas; as these apparatuses can also be used in other analogous operations occurring in the chemical and metallurgical industries, we are going to discuss the principle types.

The most widely used tar extractors are the ones of the Pelouze and Audouin type. They are built in the United States by the Gas Machinery Company, Cleveland, Ohio. Fig. 236 shows the general view of a tar extractor, Fig. 237 the drum, and Fig. 238 a cross-section.

This apparatus consists mainly of an outer cylindrical cast-iron

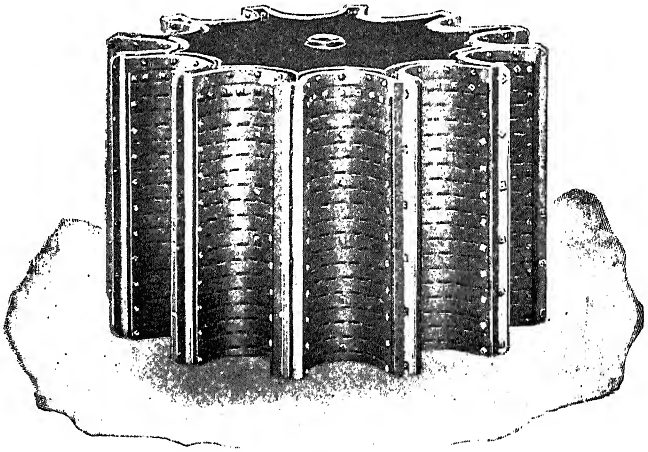


FIG. 237. DRUM OF TAR EXTRACTOR.

cover, provided with inlet and outlet openings for gas and overflow, for products of condensation, and contains a drum of perforated sheet steel counter-balanced by a weight on the outside, the connection being made through a hydraulic seal on top of the apparatus. The drum constitutes the extractor proper. The inner sheet is perforated. with rows of closely spaced round holes, and the next sheet with large rectangular slots, so arranged as to offer a blank surface opposite the small holes of the inner sheet. The two outer sheets are similarly arranged and are provided to increase the efficiency of the apparatus.

On entering the inlet the gas ascends into the cylindrical chamber,

passes through the perforations of the drum, and is divided into small jets, which strike against the solid surface sheets placed close

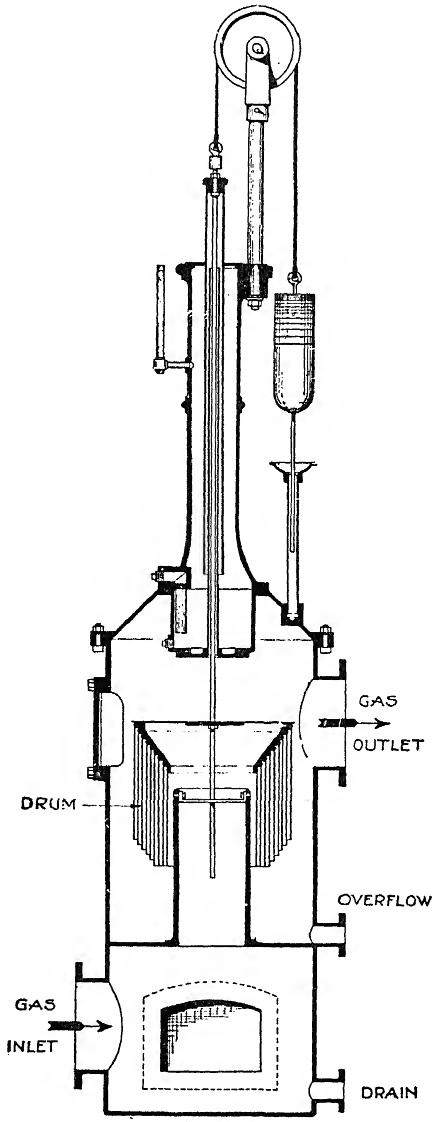


FIG. 238. CROSS SECTION OF TAR EXTRACTOR.

to the perforated plates. In passing through the small perforations the liquid molecules are wire-drawn, and therefore brought into

close contact with one another, the action being completed by contact with the solid surface upon which the tarry matter is deposited,

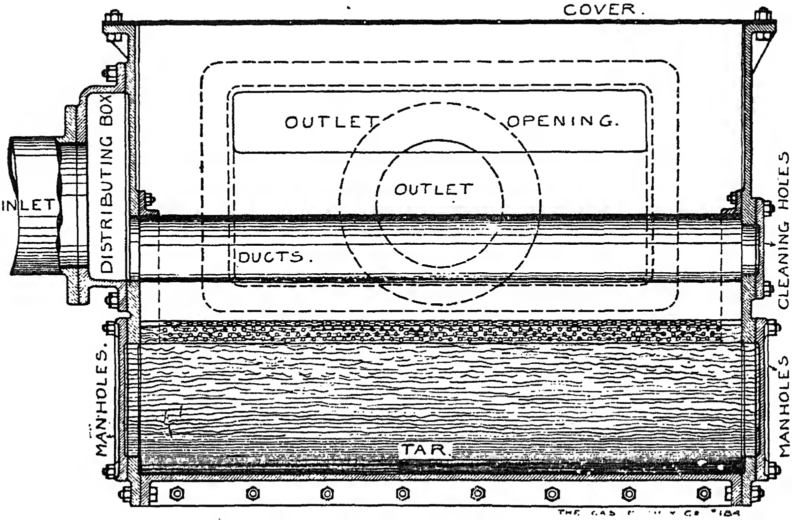


FIG. 239. SECTION THROUGH WASHER PARALLEL WITH DUCTS.

whence it flows down the surface of the plate into the annular tar chamber, and from there through the overflow to the tar well.

The drum properly balanced is capable of acting as its own regu-

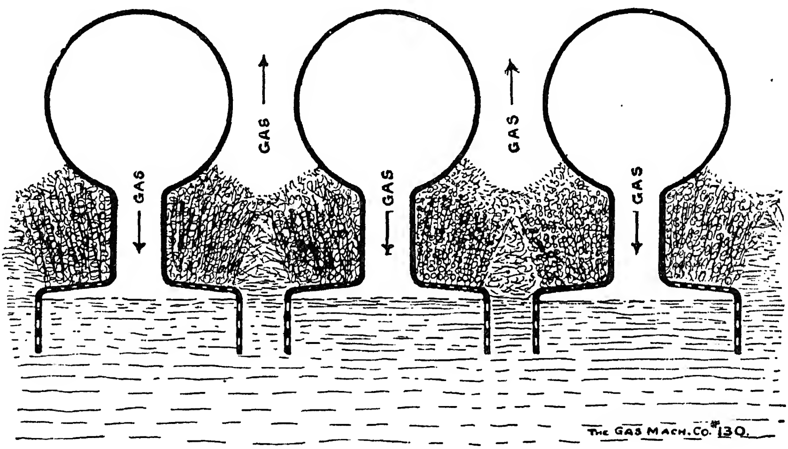


FIG. 240. CROSS SECTION OF DUCTS.

lator; when there is an increased make of gas, the cylinder rises, and a great number of perforations are exposed to the passage of the gas.

Separation of Gases from Gases. For separating gases from gases, the absorption process is used in practice. The gas not absorbed by the liquor used can be collected and the absorbed gas worked up separately.

If the gas mixture consists of more than two gases, as is the case, for instance, with crude coal gas, the various gases are absorbed consecutively in various vessels.

As the liquefaction of different gases depends on pressure and

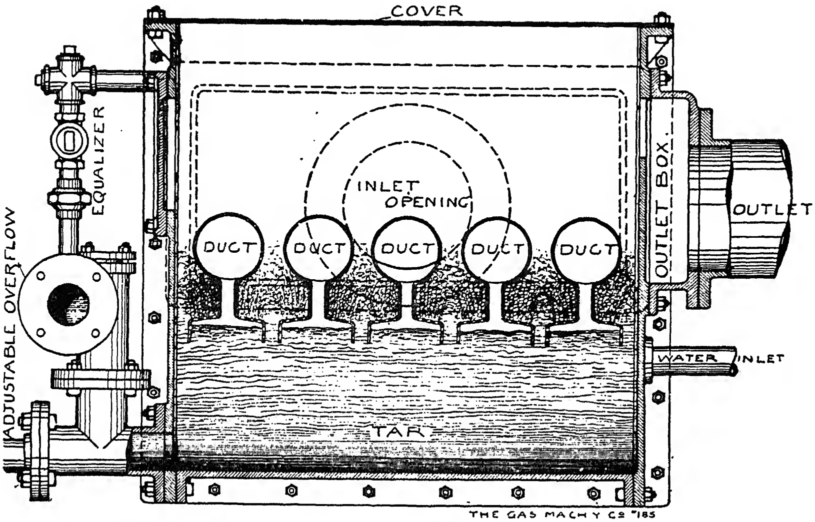


FIG. 241. SECTION THROUGH WASHER ACROSS DUCTS.

temperature, this property can also be used for separating gases (Gailey's process of drying the blast).

The following examples will show the most important types of apparatus used for separating gases:

An apparatus for removing and absorbing ammonia from gases, as built by the Gas Machinery Co., Cleveland, O., is shown in Figs. 239 to 241. Fig. 239 shows a section through the washer parallel with ducts, Fig. 240 a cross-section of ducts in operation, and Fig. 241 a section through the washer across the ducts.

This washer consists of a rectangular cast-iron box and a top cover of sheet steel. A gas inlet distributing box and a gas outlet box are bolted to the outside of two side plates and provided with openings for gas inlet and outlet connections. Ducts of sheet steel, specially perforated, extend horizontally across the inside of the

washer, one end of the upper circular part of the ducts connecting through round openings in the inlet side plate with the inlet distributing box, and the other end placed against round openings in the opposite side plates. The upper or outlet compartment above the ducts is connected with the gas outlet box by means of a long horizontal opening placed near the top of the box.

The washer is allowed to fill with liquor until the depth of seal through which the gas has to force its way will show a differential pressure of about three inches. The overflow should be set

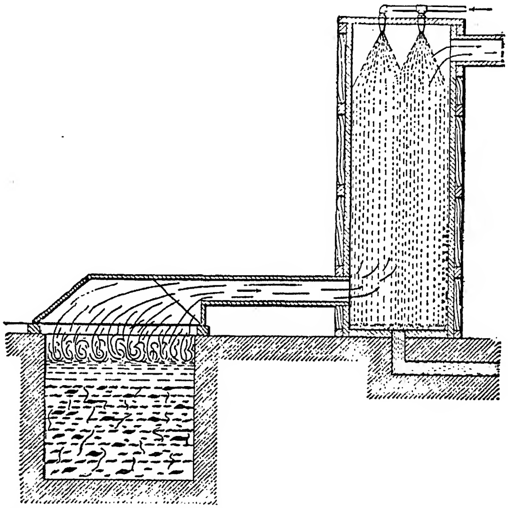


FIG. 242. ABSORPTION OF HYDROFLUORIC ACID GAS.

to allow the liquor just to pass when this point is reached, the cock in the equalizing pipe being open.

The gas first passes into the inlet distributing box and through the circular openings in the inlet side plate into the upper part of the ducts, depressing the liquor in the narrow throat of the ducts and passing through the small holes in the slanting surface of the submerged part, thereby effecting a fine distribution of the gas, which passes up through the liquor in minute bubbles.

The gas then goes into the top of the washer and through the long horizontal opening into the outlet box.

The long horizontal outlet opening extends nearly the whole width of the box, and is made of ample area to allow for the slow and easy passage of the gas. This prevents carrying entrained water with the gas.

Of entirely different construction are the apparatuses which are built by Schutte and Koerting, Philadelphia, Pa., for absorbing gases and condensing vapors. Here an extremely fine spray of water, produced by the above described spray nozzles, is applied to the gas mixture. Fig. 242 shows an installation of this type for the absorption of hydrofluoric acid gas. A hood is placed over the pit and is connected to a wooden tower, to the top of which spray nozzles are

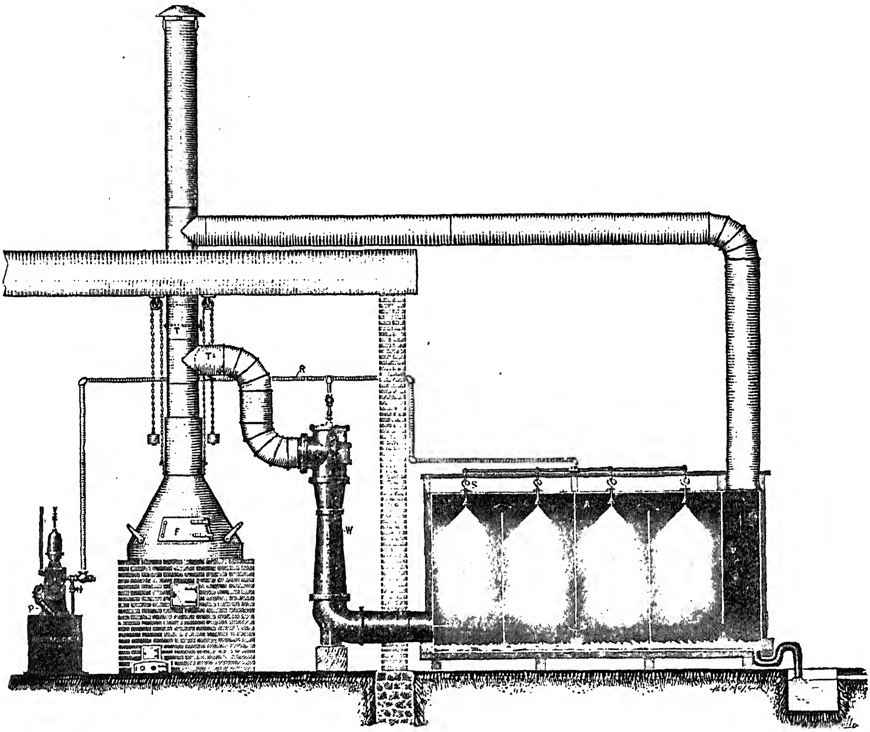


FIG. 243. CONDENSING FOUL VAPORS.

attached. The vapors free of hydrofluoric acid gas pass through the outlet to a chimney or fan.

An arrangement of the same type for condensing foul vapors is shown in Fig. 243. The fumes are sucked off by means of a water jet exhauster and pressed into the absorption chamber, in which spray nozzles are installed, which treat the gases on their way up and down in the chamber, the latter being equipped with proper partitions.

CHAPTER XIII.

EVAPORATING, DISTILLING AND CONDENSING.

Evaporating. Steam is used for evaporation either directly by passing through the liquid to be evaporated or indirectly by embedding steam pipes within the liquid.

If the nature of the liquid prevents the use of metallic vessels, stoneware vessels are generally used with direct steam. Fig. 244 shows such an arrangement in which the stoneware vessel is placed within another vessel, the space between the two being filled with a non-conductor of heat, as cement, etc.

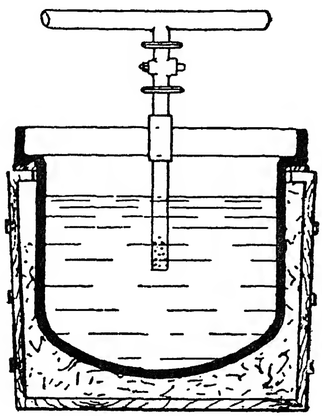


FIG. 244. STONEWARE EVAPORATOR.

If the liquid is heated by means of steam coils, the latter may be of various shape, size and material. Spiral pipes are most generally used. Care has to be taken that a moderate inclination prevails throughout, so that the condensed water can run off freely. To prevent losses of steam and in order to be able to work under pressure it is absolutely necessary to connect the end of the heating coil with a condenser, which naturally has to be watched to prevent the coil from being filled with water.

Steam coils are used for evaporation either in open or closed vessels, depending upon the nature of the liquid and of the vapors formed.

H. W. Dopp Company, Buffalo, N. Y., manufacture a number of excellent appliances for evaporating and heating purposes, ranging from 1 to 500 gallon capacity, inclusive. Fig. 245 shows their cast-iron seamless steam-jacketed kettle, which is perfectly smooth, both inside and out, is of convenient and efficient shape, cast in one piece (thus avoiding joints and rivets) and is easy to clean and to keep clean. The inner and outer shells are thoroughly braced by the system of stay bolts, not ribs (see cut), which are cast at the same

time as the shells. This allows perfect circulation and makes an absolutely safe jacket kettle. All sizes except the one-, four- and ten-gallon, which are flat bottom, are tested to 150 pounds hydrostatic pressure; these to 100 pound. Any size to stand higher pressure to order.

One might think that, because of cast iron, these kettles are easily cracked and not safe for high steam pressure. However, this is not the case, as, through the patented stay bolt construction, the unsupported area is governed at will. These kettles have been in actual successful use for years in the hardest kind of kettle service.

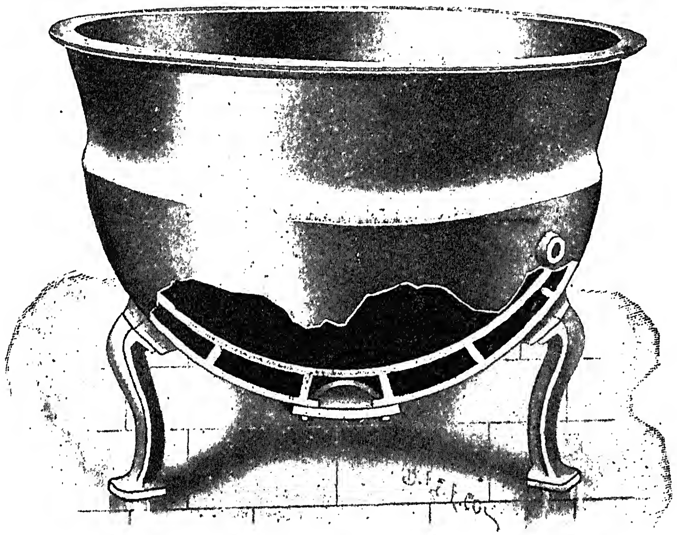


FIG. 245. DOPP'S SEAMLESS STEAM JACKETED KETTLE.

Outlets for contents are furnished with these kettles in various sizes and styles; special designed outlets are supplied, if it is necessary to have the inside of the kettle flush for preventing the pocketing of any of the material.

Bracket lugs for attaching agitators and mixers are regularly furnished with these kettles on 65-, 80- and 100-gallon sizes. Separate lugs are carried in stock by this firm, so that any size kettle can be equipped with a bracket lug on order, or, if it is so desired and time will permit, any size can be originally cast with this lug.

Kettles of one-gallon capacity are supplied on fixed legs; 4- to 125-gallon capacity on removable legs, as shown in the cut. All

other size kettles are fitted with legs as shown in the case of the high-jacketed kettle, which is described below. This firm also has a great many different size leg patterns, to give customers various

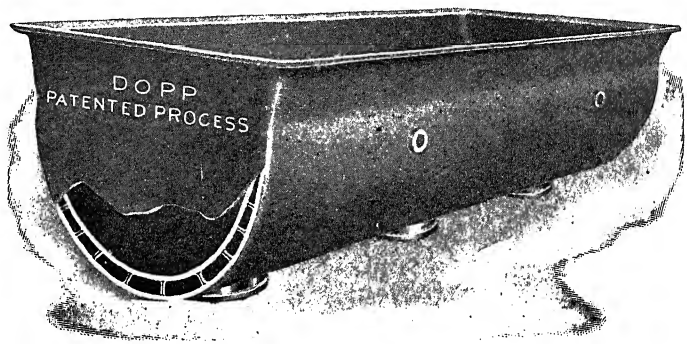


FIG. 246. RECTANGULAR KETTLE.

height from floor to outlet or rim of kettle. Kettles up to and including 175-gallon capacity are carried in stock, while the larger sizes are furnished on order, as they invariably have some special

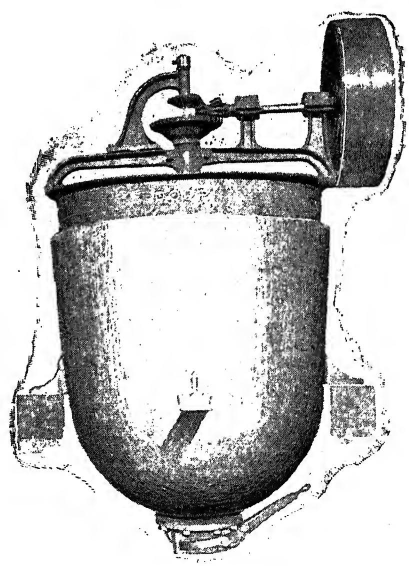


FIG. 247. HIGH JACKETED KETTLE.

features, which can be better embodied in making original castings.

Steam connections, both inlets and drips, are as follows on these

kettles: One gallon, $\frac{1}{2}$ inch; 4 to 50, $\frac{3}{4}$ inch; 50 to 200, 1 inch; 200 to 500, inclusive, $1\frac{1}{4}$ inch; two inlets on opposite sides near the top of the jacket, and one drip flange at the bottom are regularly supplied.

The H. W. Dopp Company has successfully developed a method of finishing the interior of their kettles, mixers and vacuum pans with a heavy coat of electrolytically deposited copper or nickel, which gives great satisfaction where the use of cast iron is prevented by the nature of the chemicals used. These kettles take the place of enameled kettles, and where they can be used, of course, are very much superior, as the best enameled kettle will crack if not handled properly and according to directions. It is well known that by pouring a cold liquid into a hot enameled kettle the enamel will crack.

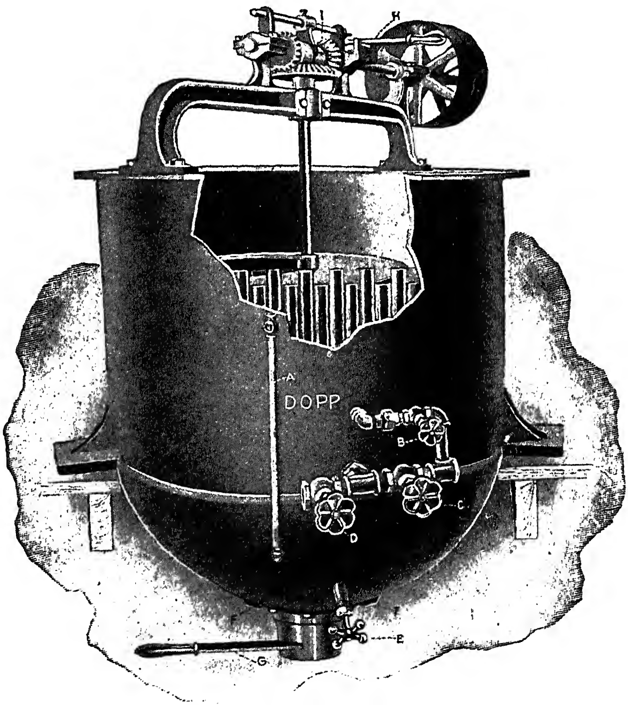


FIG. 248. SOAP CRUTCHER.

A seamless steam-jacketed rectangular kettle is shown in Fig. 246. This firm also makes high-jacketed kettles for use, where it is desired to have the substance being treated in contact with heat as much as possible. As seen from Fig. 247, this kettle is considerably

higher in proportion to the diameter than the standard seamless kettles described above.

The high-jacketed kettle is generally equipped with an agitator consisting of paddles of various shapes. The shaft, which is supplied with an oil catch cup to prevent oil from getting into the substance, is driven by a cast-iron worm wheel with steel worm.

The remelting crutcher (for soap works), built by the same firm, is constructed along the same lines as the seamless steam-jacketed kettle. A large outlet is supplied in the center of the bottom for

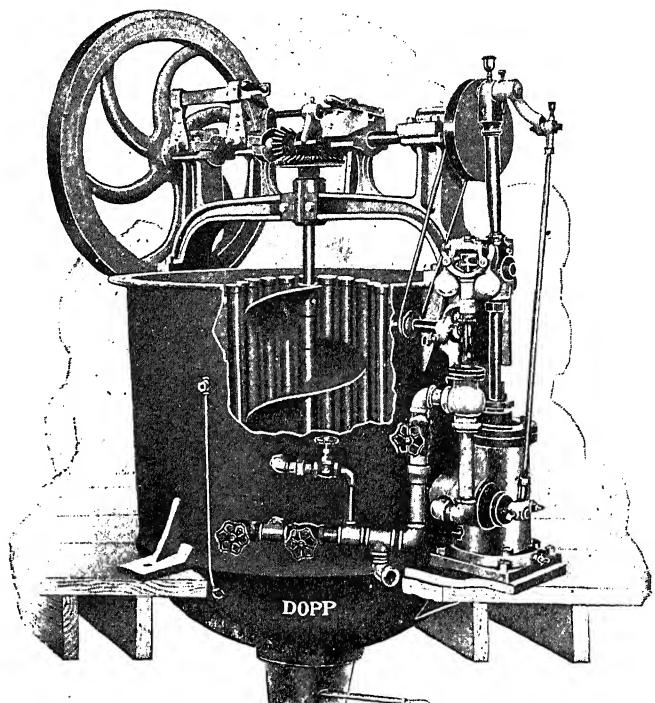


FIG. 249. ENGINE DRIVEN CRUTCHER.

the discharge of the contents. A steam heating radiator, composed of a series of vertically arranged pipes having open spaces between them, screwed into a header, is placed in the center, and through this radiator steam passes directly to the jacketed part of the kettle, which can be cut off from steam supply so that the inner cylinder only has steam. The kettle is also arranged so that connections can be made, allowing steam in the jacket only. Fig. 248 shows a

crutcher as used in soap works. A conveyor screw is placed in the center of the radiator. As soon as a portion of the soap is melted, the screw is set in motion, thereby lifting the soap and crowding it over the top of the radiator surrounding the screw, the centrifugal force forcing it out through the open spaces left between the pipes. The constant motion of the screw shears up any pieces, and thus, in comparatively short time, the largest scraps are completely cut up. and the whole kettle full of soap will be thoroughly melted. Owing to the open spaces left between the pipes composing the radiator, there is no splashing of the contents whatever, however fast the conveyor screw is worked.

If desired, moist steam may be passed through the material to be treated or cold water may be passed into the jacket and radiator to

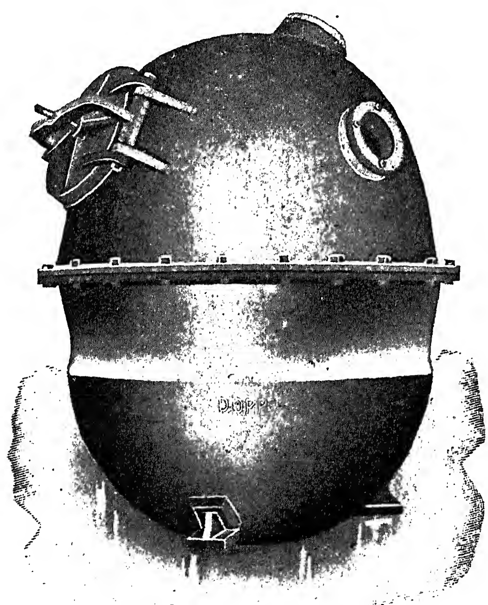


FIG. 250. VACUUM PAN.

facilitate the cooling of the material. The conveyor screw is worked by a pulley and belt, driven by power. The conveyor screw may be worked backward or forward by merely shifting the clutch that drives the bevel gearing. An engine-driven crutcher is shown in Fig. 249.

Among closed vessels heated with steam coils the vacuum evapo-

rators have to be mentioned. Sometimes steam jackets or a combination of steam jackets with steam coils are used in place of coils. These vacuum tanks are made in various shapes, the most suitable form depending on the nature of the material to be handled. Before the vapors leave the apparatus, they must generally pass through a trap provided at the top for catching and retaining any liquid particles. The apparatus is also equipped with a discharge opening at the bottom, a thermometer, a vacuum gauge, test cocks, steam, water and liquor valves, etc.

Fig. 250 shows a cast-iron seamless steam-jacketed vacuum pan, which is extensively used. This pan is built by the H. W. Dopp

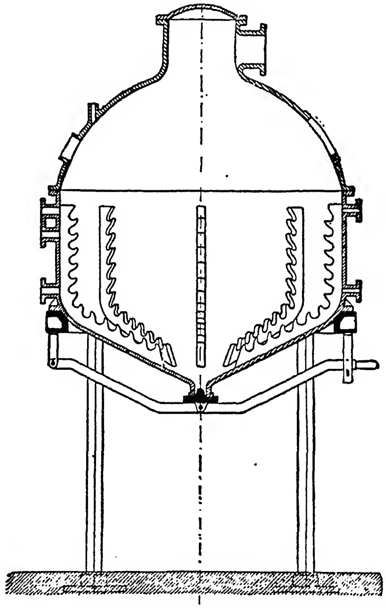


FIG. 251. EVAPORATOR MADE OF THREE PARTS.

Co., Buffalo, N. Y., and is provided with mixer attachments which are made in any form desired. It is particularly adapted for boiling and evaporating substances quickly, and in cases where the substance is to be evaporated down to a crystal or powder form. They are made from 10- to 1,000-gallon capacity, inclusive.

Fig. 251 shows an evaporator built up of three parts, each of one single piece.

Formerly steam for the steam coils was directly taken from the boiler, but at present exhaust steam is also used for this purpose.

This, however, necessitates a considerable increase of the heating area. A large heating area, however, cannot always be provided by coils. Special tubular heating structures are, therefore, frequently used, as in the various evaporators to be described below.

The steam has to enter into the vessel as near to the top as possible, while the outlet for the condensed water is provided at the bottom of the vessel. If the steam for heating is to be used at a lower pressure than the boiler steam, a suitable valve for reducing the pressure must be employed.

In stoneware vessels, that part which is hit by the entering steam is preferably protected by a shield of sheet metal, while in metallic vessels joints between different parts are often made by screws. Different parts of stoneware vessels are preferably joined by means of Portland cement.

For substances which have a boiling point of over 200 degrees superheated steam has to be used, and in such cases the evaporator

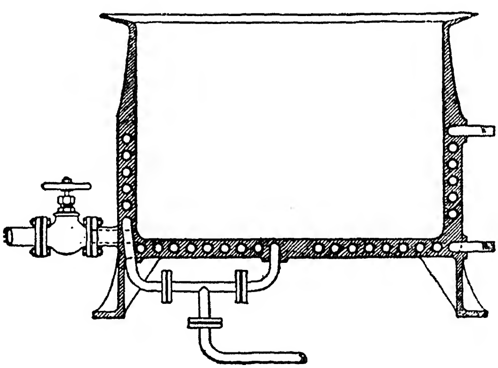


FIG. 252. COILS CAST INTO WALLS OF EVAPORATOR.

shown in Fig. 252 is successfully employed. In this case the coils are cast into the walls of the vessels, which may also be provided with a stirrer.

According to H. Claassen the main features of modern methods of evaporation are the use of a high vacuum and the principle of multiple effect evaporation. The steam evolved in evaporation may be led into another set of steam coils and used again for evaporation. Two apparatuses coupled together represent a double-effect evaporator; three a triple-effect evaporator, etc. We will now describe the most important types of multiple-effect evaporators used in the chemical industries.

In the Yaryan evaporator (Fig. 253) the material is kept in very rapid motion so as to be in contact with the heated surface only for a moment. The liquid to be concentrated is fed into one end of a three-inch tube coil, fifty feet in length, and the rate of feeding is so adjusted that the given heating surface will concentrate the liquid

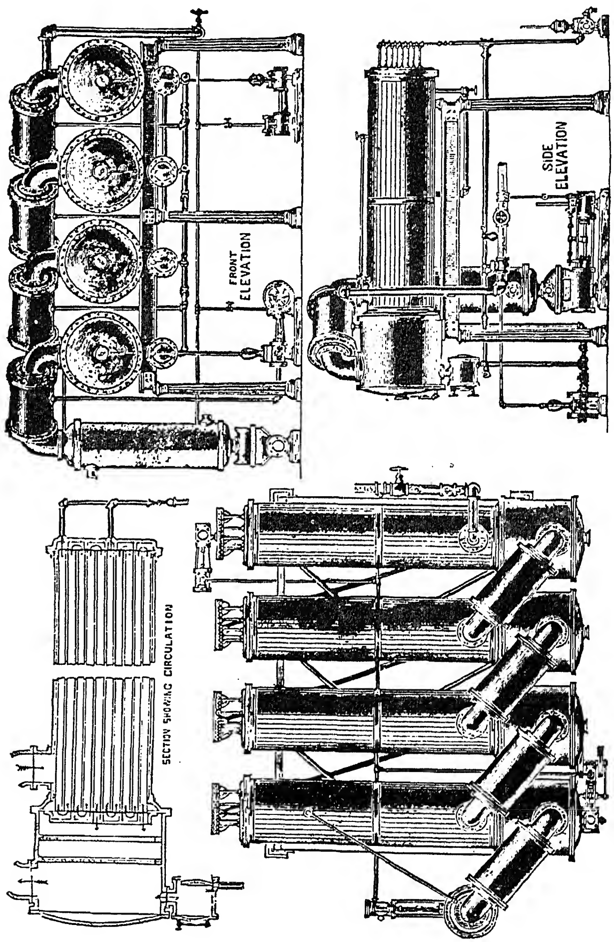


Fig. 253. Yaryan Evaporator.

to the desired density. Only in extreme cases is it necessary to return the concentrated liquid for reëvaporation.

Exhaust steam can be used in this system without difficulty. For liquids that require a high temperature for evaporation Yaryans are built that can be used under 100-pound pressure with perfect safety.

In the operation of this apparatus the steam is led into the cylin-

drical chamber surrounding the coils in the first effect. The liquid to be concentrated is fed into the first tube of the return bend coils of the first effect in a small but continuous stream, and immediately begins to boil violently. It becomes a mass of spray, containing, as it rushes along the heated tube, a constantly increasing proportion of steam.

The inlet end of the coil being closed to the atmosphere, and the steam being continually formed, the contents are propelled through the tubes at a high velocity, finally escaping from the last tube of the coil into the separator.

Here the steam or vapor, with its entrained liquid, which has been reduced in volume by the evaporation, is discharged with considerable force against baffled plates, which separate the liquid from the steam, causing the former to fall to the bottom and permitting the latter to pass off through an ingeniously contrived catch-all, which effectually removes any remaining liquid, into the chamber surrounding the tubes in the second effect, where its heat is utilized for further evaporation of the liquid. The liquid from the bottom of the separator of the first effect passes into the coils of the second effect, and in it the same process takes place as in the first effect, and so on through the entire series, whether a triple, quadruple, etc., effect is used, the volume of the liquid being constantly reduced in each effect.

The steam from the final effect goes to the condenser and the vacuum pump, a high vacuum being thereby maintained in the separating chamber and consequently in the coils. Hence the boiling point of the liquid is at a lower temperature than that of the surrounding steam, and by the condensation of the steam from the previous effect upon the cooler pipes in the next effect a less perfect vacuum is maintained in the preceding effect.

Thus we have in the series of effects a gradual reduction of pressure and in boiling temperature, and this automatically adjusts itself, whatever the number of effects, so that the liquid is brought to the boiling point by the steam produced by its own evaporation in the preceding effect. Since a complete condensation of the vapor surrounding the coils in each effect takes place, and the boiling point of the liquid within the coils is below the temperature of the vapor outside, not only sensible heat available on account of the temperature difference outside and inside, but also the latent heat

of the condensing vapor is absorbed by the liquid and used for evaporation.

Ordway has designed a concentrator and separator which is based on the principle that a liquid concentrated to the crystallizing point will, if cooled, precipitate more rapidly and give a more complete separation. While the liquid is being concentrated it comes in contact with heating and cooling surfaces alternately, and in its passage from a cooling surface to a heating surface it passes through a precipitating chamber, where there is sufficient space to collect the crystals for removal. Should the original liquid be sufficiently cool, it is used as the cooling medium before being fed into the evaporator.

The crystals are continuously removed from the precipitating chamber to a draining tank, which is under the same vacuum as the evaporator, and the drained liquid continually returns by gravity to the evaporator for reëvaporation. When the drain tank is filled with the crystals, the circulation is stopped, or changed over to a second draining tank, and the crystals are removed from the first tank in a comparatively dry state.

The Ordway concentrator (Fig. 254) is made up in sections, the different sections having the same proportion of heating surface to cooling surface and of vapor chamber to precipitating chamber. These sections are flanged in such a manner that they may be bolted together to make up one evaporator effect of any size or capacity required, and when an increase of capacity is desired, all that is necessary is to add one or more sections to each effect, thus avoiding the necessity of installing a new plant.

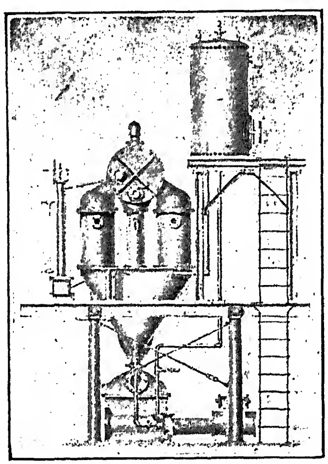


FIG. 254. ORDWAY EVAPORATOR.

The Ordway is built for single or multiple effect, and is provided with all the convenient appliances of an evaporating plant, such as eye-glasses in each effect, for observing the action of the liquid while boiling, a tester for testing the density of the liquid, water gauge, automatic feed regulator, condenser, pumps and all intermediate piping.

The submerged tube type of evaporator is represented by (1) the so-called standard evaporators, consisting of vertically cylindrical shells fitted with vertical tubes, the steam being supplied to the outside of the tubes and by (2) the horizontal tube apparatus, which carries the steam inside the tubes submerged in the boiling liquor. A well-known type of the latter is the old Swenson evaporator (Fig. 255), which shows a small double effect on this system. The shell

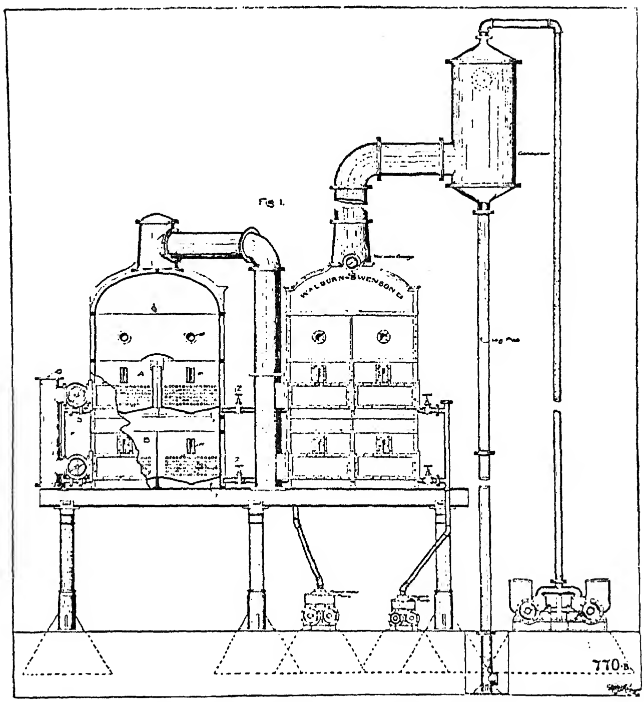


FIG. 255. SWENSON EVAPORATOR.

is of heavy cast-iron plates; tubes of seamless copper or steel, inserted in place by the use of elastic gaskets and packing plates, making possible their ready removal. The advantages of this type consist of the shallow heating surface, the large area provided for the liberation of the generated vapor, absence of expansion troubles at the tube joints, ease of operation, and absolute control of liquor density. When desired the steam chests can be so arranged that any desired percentage of increase of heating surface can be secured by merely adding the necessary tubes.

The latest development in multiple effect apparatus is the Zaremba

round-body evaporator, shown in Figs. 256 and 257, which combines all the advantages of the Swenson heating surface with the structural advantages possessed by the shell of the standard type. It will be noted that the joints are reduced to a minimum, internal braces are eliminated and that the pans can stand a considerable

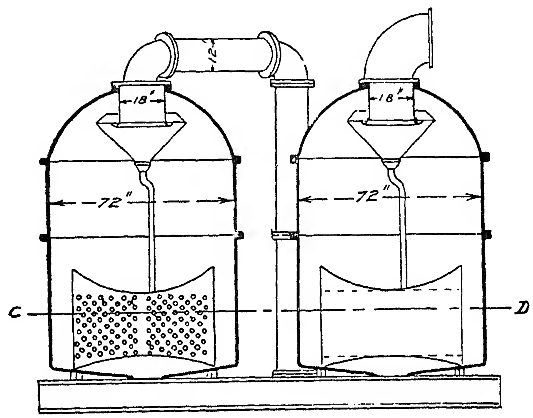


FIG. 256. ZAREMBA EVAPORATOR, VERTICAL CROSS SECTION.

internal pressure without injury. Furthermore the down-takes are so designed that a much better circulation is obtained, giving a heat transmission per square foot of heating surfaces over 20 per cent. greater than is the case with the Swenson. In this connection, it

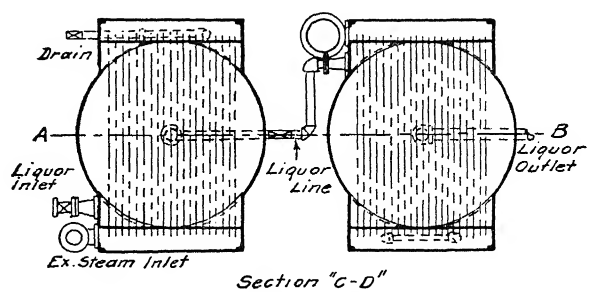


FIG. 257. ZAREMBA EVAPORATOR, HORIZONTAL CROSS SECTION.

should be borne in mind that the old style horizontal heating surface gives 30 per cent. better transmission than the vertical tubes of the standard evaporator.

The Newhall evaporator, as built for chemical works, etc., is

shown in Figs. 258 and 259. *A* is the steam trunk, from which the evaporator draws steam of the desired pressure. A_1, A_2, A_3 are compartments from which the tubes are supplied with steam; *B* are the steam-heated tubes; *C* the boxes for condensing water at the lower end of the apparatus; *D* a float box with disk valve; *E* the space for the vapor and boiling solution; *F* a baffle float box with disk valve; *G* the outlet for vapors and pipe connection between

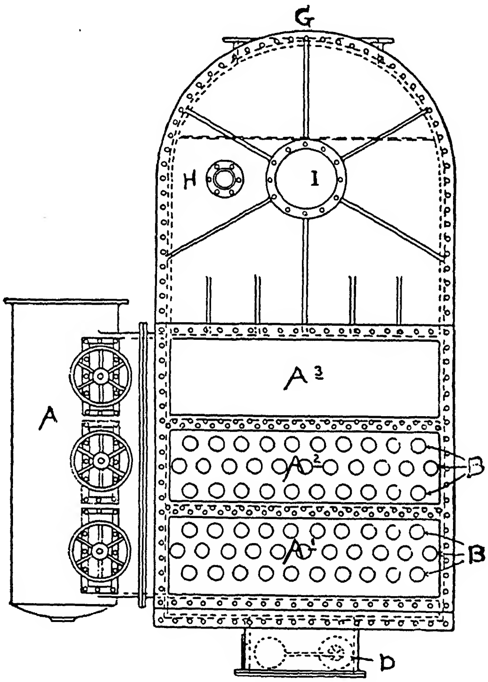


Fig. 258. Newhall Evaporator.

this effect and the next one; *H* eight glasses to inspect the boiling conditions; *I* manholes; and *K* removable covers on the steam boxes.

A vertical longitudinal section through the body of a Lillie evaporator is shown in Fig. 260. The vapor ends of the tubes are closed. The condensed steam inside the tube flows back in the "steam end" and thence through a steam trap usually into the steam end of the next coolest body.

The cut shows the circulation of the solution over the tubes as a heavy shower maintained by a centrifugal pump. The circulation is independent of temperature, and on the tubes there is no depth

of solution through which vapors formed would have to force their escape.

The Kestner evaporator (Fig. 261) utilizes the principle of film

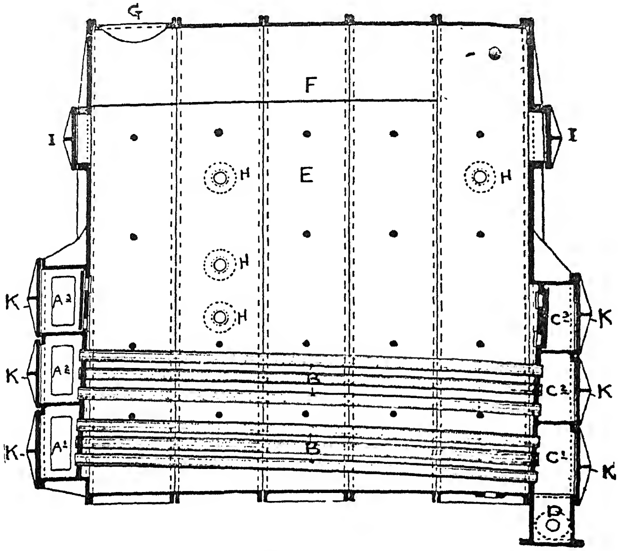


FIG. 259. NEWHALL EVAPORATOR.

evaporation in a simple manner. The design of this apparatus is such that the film is forced to cling to the heating surface independent of gravity, instead of being forced away from the hot surface by the steam disengaged. This means a very effective use of

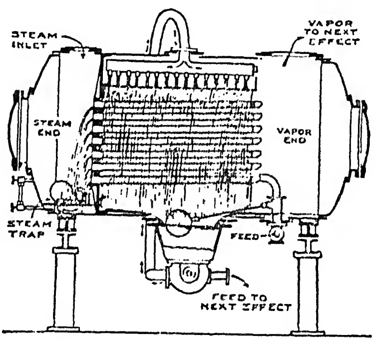


FIG. 260. LILLIE EVAPORATOR.

the heating surface and the possibility of concentration to the desired degree on one passage through the tubes.

This "climbing film" evaporator and the distribution of the film over the heating surface is made automatically by the disengagement of the steam. The tubes in a Kestner evaporator are ordinarily vertical and are about twenty-three feet long. The liquid is fed in at the bottom and the supply is so limited that the tubes are practically empty.

At the start the liquid begins to boil in the tubes and very shortly such a violent ebullition occurs that the vapor, occupying many times the volume of the liquid, rushes through the tube at such a velocity that it carries with it against the hot walls of the tube a thin film of liquid. This liquid film, together with the vapor, is discharged against suitably designed vanes of a centrifugal separator. In this way the concentrated liquid is whirled against the walls of the vapor belt and the vapor, thoroughly separated from the liquid, passes off to the next pan or condenser.

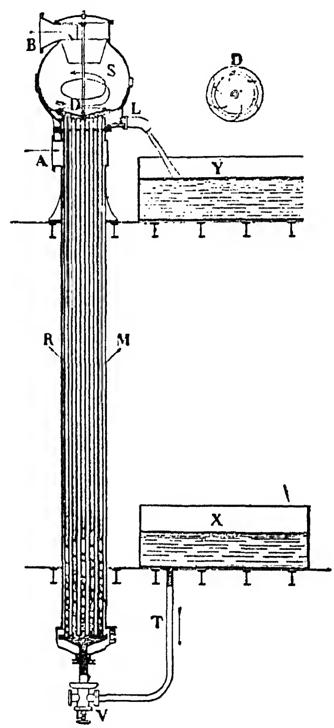


FIG. 261. KESTNER EVAPORATOR.

From this description it will be readily understood that the liquid is automatically elevated and evaporated in passing, the concentration depending on the amount of liquid admitted. This results in an evaporator essentially different in appearance from others.

Distilling. A special case of evaporation is distillation for the purpose of separating liquids from each other. Every distilling apparatus consists, as a rule, of three parts: (1) The vessel containing the liquids to be separated, (2) the cooling apparatus, and (3) the vessel for receiving the distilled liquid.

The setting of a cast-iron still is shown in Fig. 262. Eight lugs cast into the shell of the kettle rest upon an iron ring in the brick work. Eight openings of various size are provided in the ring (those nearest the stack being the smallest), so that the fire gases are forced to play uniformly around the walls of the still. The fire gases pass through these openings to the stack.

On account of the low location of the grate, the flame does not come in contact with the vessel, whereby the life of the plant is considerably prolonged.

Many evaporators can be transformed in a simple way into a distilling apparatus (Fig. 263).

A distilling apparatus for making sulphate of ammonia or concentrated ammonia solution from gas water is shown in Fig. 264.

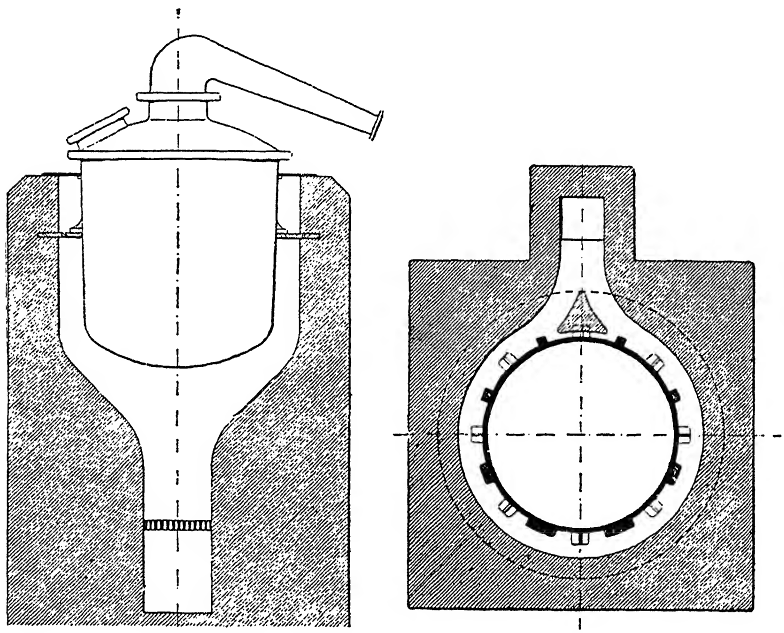


FIG. 262. CAST-IRON STILL.

In this apparatus, which was designed by J. L. C. Eckelt, in Berlin, steam jet blowers are used instead of coils, whereby a more thorough mixture of gas, water and milk of lime is effected, the capacity of the apparatus is increased and the steam is better utilized. This apparatus consists of three parts, the lower boiler, the upper boiler and the tower on top of the latter. In the manufacture of sulphate of ammonia, the ammonia liquor to be distilled flows through pipe *a* from a higher reservoir into the preheater *B*, and then through *b* into the tower. Steam enters the lower and upper boilers through valve *c*.

By means of a steam jet blower the gas water is constantly kept in motion and thoroughly mixed with the milk of lime pumped in

from the reservoir *D* through pipe *d*. The dissolved ammonia gas rises with the steam through the tower, while the water flowing the opposite way condenses the steam and liberates the ammonia.

The rising ammonia passes through pipe *g* into the saturating box *C* and is absorbed by the sulphuric acid contained therein. Foreign gases and vapors are carried by pipe *i* to a fireplace or stack. Through valve *l* the lime mud is allowed to drop into the lower boiler from time to time. Through cock *f* the mud is discharged from the lower boiler.

The distilled gas liquor runs off through cock *e*. When the apparatus is stopped, the stopper *k* of the box *C* is removed to prevent the formation of a vacuum in pipe *g* by condensation of the ammonia gases.

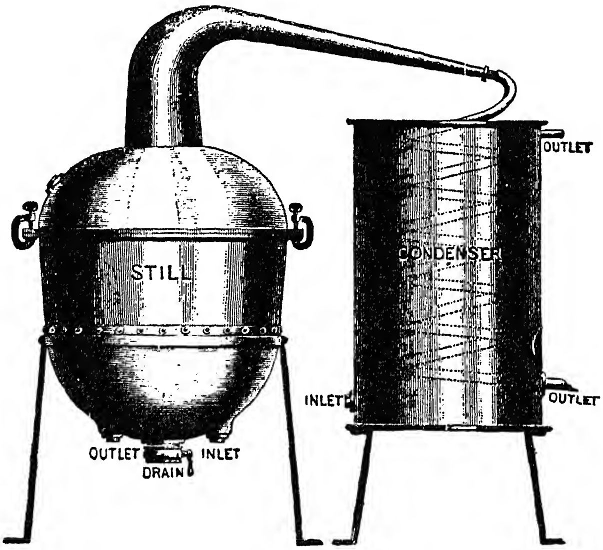


FIG. 263. DISTILLING APPARATUS.

For treating certain substances, distillation in vacuo is frequently applied. In this case the vessel, which serves as receiver for the distilled substance, is connected to a vacuum pump or to a steam jet blower.

A simple vacuum plant, in which the vacuum is effected by a Koerting steam jet exhauster, is shown in Fig. 265. *D* is the vacuum kettle, *C* the condenser, *K* the cooler, *E* the exhauster, *S* the steam supply.

Condensers. The condensation of steam in a separate chamber from the engine cylinder instead of by a spray of water injected into the cylinder itself after the steam piston had completed its stroke, was an invention of James Watt, in 1765, for which he

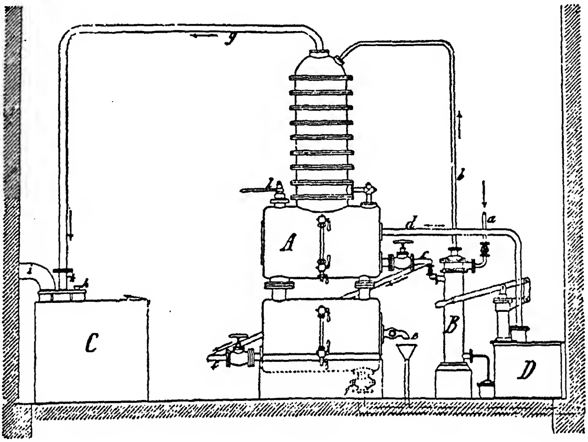


FIG. 264. DISTILLING APPARATUS FOR SULPHATE OF AMMONIA.

received letters patent in 1769. It was the first step in the history of the steam engine in the direction of increased efficiency from the atmospheric engines in use at that time, towards the present era

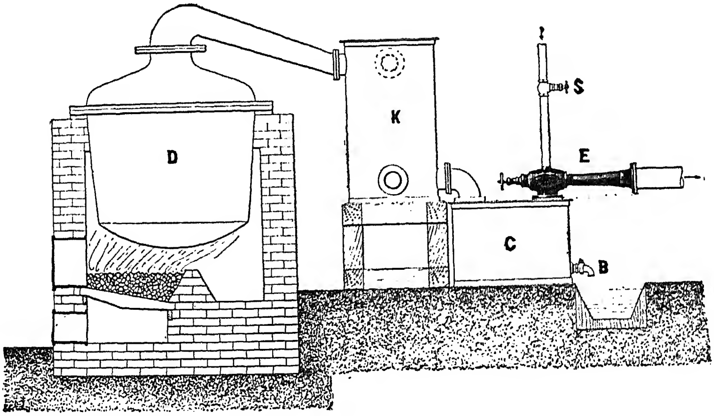


FIG. 265. DISTILLING UNDER VACUUM.

of high steam pressure and multiple expansion condensing engines.

Where a sufficient quantity of water suitable for boiler feeding purposes is available, the jet condenser, being the simplest and

easiest to operate, is preferable. Where, however, water suitable for boiler feeding is not available, a surface condenser may be used. In this type the steam is condensed in a condensing chamber on the surface of tubes through which cold water is circulating, and the distilled water so furnished may be again fed to the boilers. Where any considerable amount of cylinder oil is used, some provision must be made with surface condensers to remove this oil before the water is fed to the boilers. With either type the quantity of water to be circulated through the condenser should be from 20 to 40 times the quantity of steam to be condensed, depending upon the temperature of the water available for condensing purposes.

American condenser manufacturers have recently introduced several types of self-cooling condensers by which the hot water delivered from the condenser pumps can be cooled and re-used, so that with water sufficient in quantity for boiler feed purposes only, the plant may be located at any convenient point, and still retain the fuel saving and other benefits of high steam pressures and condensers.

Among the different types of jet condensers the Koerting jet condenser, which is built by the Schutte and Koerting Company, Philadelphia, Pa., is widely used on account of its simplicity and reliability. In this condenser the exhaust steam enters with the cooling water into the condensing chamber, where the steam is condensed direct by the water. This physical process being completed, the water jet, united with condensed steam and the non-condensible gases, has to be discharged against the pressure of the atmosphere. This mechanical work is done by the same water jet, which, for that purpose, has to enter the condensing chamber in a solid jet, and after the steam is condensed enters the discharge cone or tail-pipe with such a velocity that it overcomes the pressure of the atmosphere, being powerful enough to expel the air. To keep the jet straight it is surrounded by a combining tube, in which ports are drilled at a suitable angle, through which the steam from the condensing chamber enters and is condensed by the jet. The holes are cut in an angle, tending to give the water a high velocity. These condensers are manufactured in two types, eductor and induction condensers, each having its separate and distinct application.

Eductor condensers require a head of water of twenty feet, and work with absolute certainty under all conditions of load variation,

and the air and non-condensable gases are discharged with the water without the assistance of air pump. An eductor condenser is shown in Fig. 266. The advantages of these condensers are:

1. Absence of air pumps, which require a large amount of power and cost of maintenance.

2. Full water openings, preventing any clogging up of the water supply.

3. Short exhaust pipes between the engine or turbine to condenser; hence there is no trouble on account of a leaky exhaust pipe.

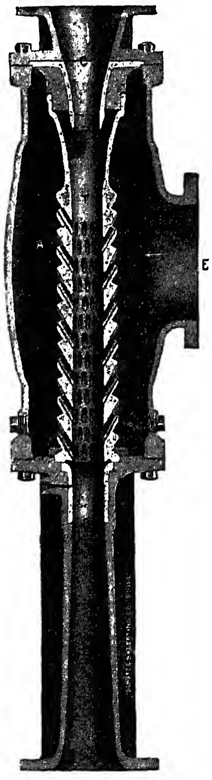


FIG. 266. EDUCTOR CONDENSER.

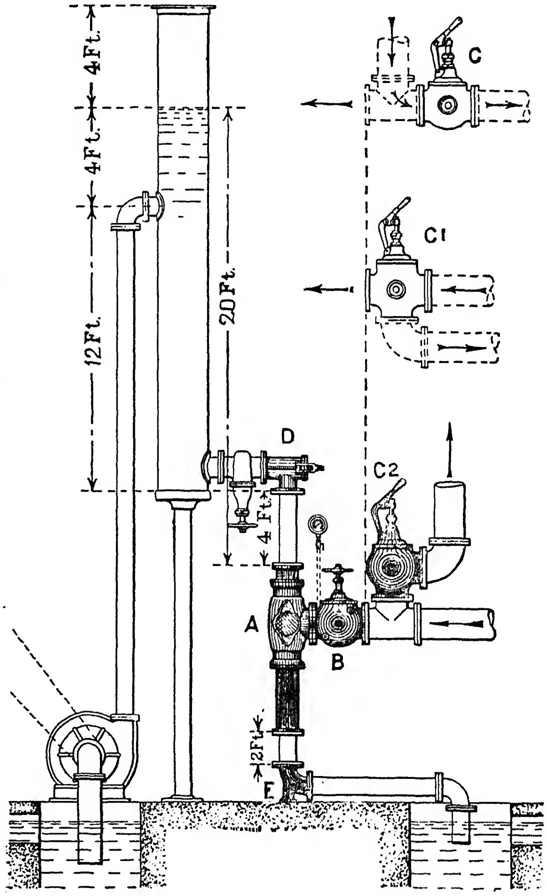


FIG. 267. ATTACHMENT OF EDUCTOR CONDENSER.

4. On account of the low cost of these condensers it is possible to adapt condensation for a steam engine during the summer, while during the winter the exhaust is used for heating purposes.

The attachment of an eductor condenser is shown in Fig. 267. *A* is the condenser, *B* the water check, *C* the free exhaust, *D* the strainer, *E* the foot elbow, C_1 and C_2 are variations of free exhaust.

Except with small engines, it is advisable, wherever practicable, to have a separate condenser for each steam unit. If this cannot be arranged a drum of sufficient area, into which a number of engines exhaust, can be arranged and the condenser attached. Such plant has the advantage of low cost and simplicity.

It is best to deliver the water from the pump into an intermediate overhead tank, fixed at suitable level to give the necessary head of water for the condenser, but the water may be delivered direct from a centrifugal pump into the condenser.

When an intermediate overhead tank is used, any air drawn in at the pump glands, or at the joint or suction pipes, escapes at the tank, and the vacuum is not affected as in the case when the air is delivered with the water direct into the condenser. The tank also has the advantage that, when a number of condensers are used, any one of the pumping sets can serve for any of the condensing units, thus giving greater security against breakdown. In most of the recent installations of eductor condenser plants in power stations, centrifugal pumps driven by electric motors have been adopted, which are comparatively low in first cost, occupy small space and require little attention.

Induction condensers lift their own water supply, and are applicable only to engines subject to load variations at regular and not frequent intervals, such as centrifugal pumps, mine pumps, fans, etc. The vacuum is created by the condensation of the exhaust steam on a column of water in motion, which is induced and maintained by the impact action of the exhaust steam through passages inclined in the direction of the current, thus assisting a natural fall of water, if there be such, or maintaining it unaided, if water has to be lifted from a lower level.

The induction condenser, as shown in Fig. 268, is equipped with a regulation of water supply and with a sleeve to cover the ports of the combining tube, according to the steam used. According to the load of the engines, the water ram, as well as the sleeve, are set and remain in this position during the time of operation of the engine under the conditions for which the ram and sleeve are set.

This condenser is also highly adaptable where only a certain head

is at disposal, whereas the rest of the water has to be made good by the action of the exhaust steam itself.

The head of the condenser can be turned at right angles or in any direction admissible by the bolt spacing, so as to be most convenient for pipe connections or for handling.

When all the water is supplied under pressure, the opening

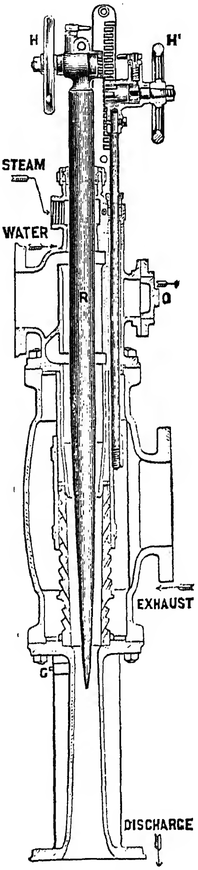


FIG. 268. INDUCTION CONDENSER.

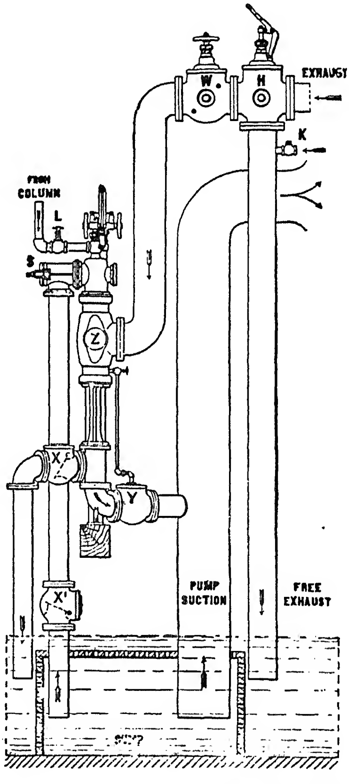


FIG. 269. CONDENSER WITH AUTOMATIC DISCHARGE VALVE.

marked "steam," as also the opening *C*, are blanked. When water is taken under suction, and pressure water used for starting, the opening *C* is blanked. When water is taken under high suction and steam used for starting, then a check valve is attached to opening *C* and the overflow pipe connected to discharge free or into the main discharge pipe.

The condenser with automatic discharge valve, shown in Fig. 269, is used for taking water supply from sump and automatically discharging into the suction pipe of a pump. This arrangement is particularly desirable in deep mines, etc., having a great discharge height and consequently greater volume of exhaust in proportion to the volume of water pumped.

Under these conditions, if discharge from condenser were returned to sump, the temperature of the sump water would greatly increase, causing annoyance, damage to the timber, and detract from the effectiveness of the condenser. By discharging directly into the suction of the pump the warm water is removed as it is produced, and the sump water remains cool.

The danger of having steam enter the pump, through accidental stoppage of pump or condenser (whereby the action of the pump is disturbed), is entirely eliminated by the automatic action of the

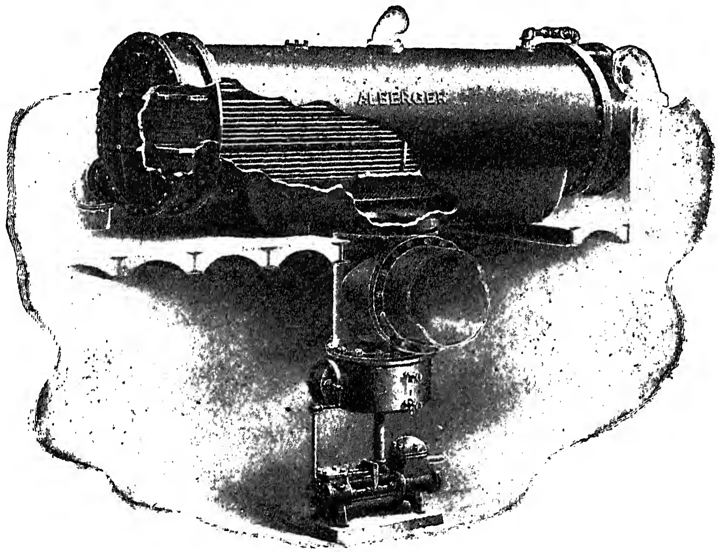


FIG. 270. COUNTER CURRENT SURFACE CONDENSER.

discharge valve *Y*, which closes when the vacuum in the condenser is destroyed, while the condenser is free to re-start through check *X*, and as soon as the condenser resumes its action the valve *Y* will open automatically, diverting the discharge from condenser again into pump suction. *Z* is the condenser, *H* the free exhaust valve, *W* the water check valve, *S* the basket strainer, X_1 the suction check and *K* the air check.

The "Alberger" type of counter-current surface condenser is shown in Fig. 270. Its working is easily understood from the illustration.

Frequently the available water supply to condenser suction is insufficient, and the necessity then arises to use the whole or part of the limited supply over and over again. To prepare the water for efficient re-use, the hot water has to be cooled. Cooling plants of every description are based on the same principle: a division into spray or thin streams to be cooled by contact with air.

The Koerting spray nozzles offer the simplest means of accomplishing this at the least first cost, with no expense for repairs, absolute certainty of operation and smallest expenditure of power.

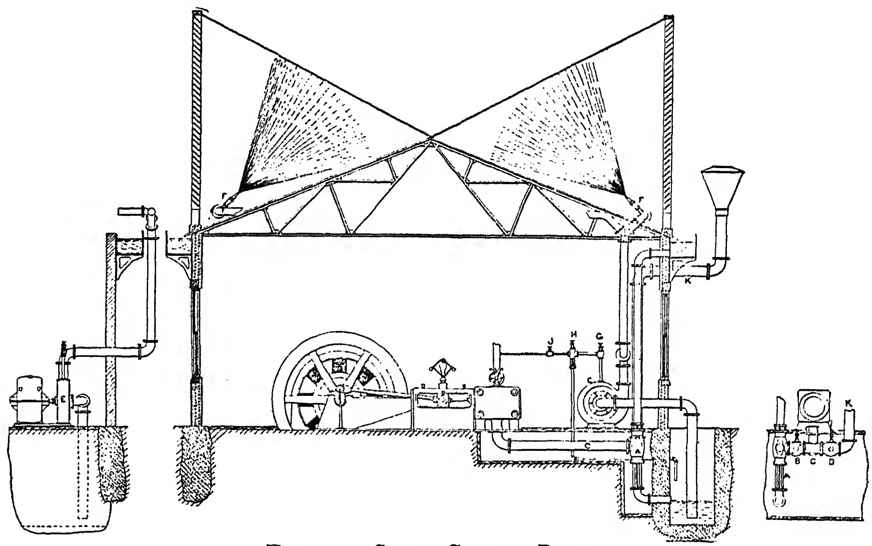


FIG. 271. SPRAY COOLING PLANT.

Fig. 271 shows a spray-cooling plant on the roof of an engine house. *A* is the condenser, *B* the horizontal check valve, *D* the free exhaust valve, *E* the centrifugal pump and *F* the spray nozzles.

The water of about fifteen pounds pressure issuing from the nozzle is torn into spray, and in this form, projected through the air, creates its own continuous current. The act of disintegrating the water carries with it a lowering of the temperature, and this added to the effect of the air current reduces the water temperature to nearly that of the surrounding air, and, under favorable atmospheric condition of humidity, several degrees below the atmospheric

temperature, but at all times to a temperature sufficiently low for effective condensation.

Cooling towers are also used for the re-cooling of water. They are generally filled with boards of cypress, the air being blown through the tower by a fan provided at its bottom, while the water runs down in the interior of the tower through the openings of the filling, arriving at the bottom at a comparatively low temperature.

Noiseless Heater. A convenient device for evaporating and heat-

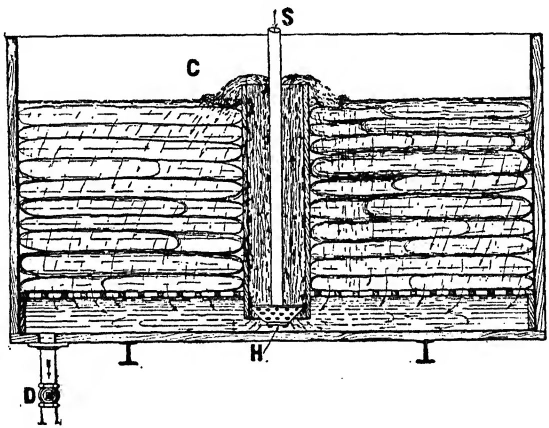


FIG. 272. NOISELESS HEATER.

ing operations is the noiseless heater (Fig. 272), which is made by the Schutte and Koerting Co., Philadelphia. The illustration shows an installation for boiling and cleansing yarn. *H* is the heater, *D* the drain, *S* the steam. The tank contains two bottoms and, reaching from the top almost to the lower bottom, is constructed a square wood trough, in which the noiseless heater is installed. The heater boils the water in the washing soda and circulates the liquor in the best manner. These heaters entirely obviate the noise connected with direct steam heating. They discharge in the form of an inverted cone, offering a large surface and thus causing rapid condensation.

CHAPTER XIV.

DRYING APPLIANCES.

Drying at Ordinary Air Pressure. The drying of raw materials and finished products is in a good many cases an important part of a chemical manufacturing process and should be performed with the greatest possible economy. To dry a substance means to remove adhering liquid from it; in general, mechanically admixed water. It is always of advantage to mechanically remove (by dripping, filtering, etc.) the largest possible quantity of water before subjecting the material to the drying process proper. The water that cannot be mechanically removed has to be removed by evaporation by contact with atmospheric air, which in many cases has to be preheated. Admission of air is especially necessary if the nature of the material to be handled necessitates the application of a temperature below 100° C. at ordinary atmospheric pressure. The simplest way of artificial drying is shown in Fig. 273. The material

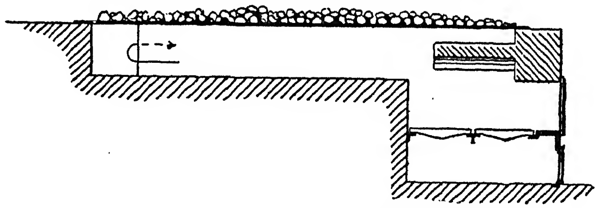


FIG. 273. SIMPLEST METHOD OF ARTIFICIAL DRYING.

to be dried is put upon a platform made of iron or clay plates and heated by the fire gases passing through flues which are provided below the platform. In place of direct firing, frequently steam heating is employed, making use of exhaust steam.

This method of drying is very primitive and should be used only where large quantities of heat, that otherwise would be wasted, are at disposal; the transmission of heat in this apparatus is not at all economical and the material to be dried remains cold on the surface. To overcome the latter disadvantage the material is frequently stirred, either by hand or mechanically.

Somewhat more efficient are the so-called drying chambers; in

these rooms, which are made of brick-work, wood or insulated iron, the material to be dried is distributed loosely, if it is not a solid material, or in vessels or pans, if soft or pulverulent. The heat must be sufficient and well adjustable and provision is to be made

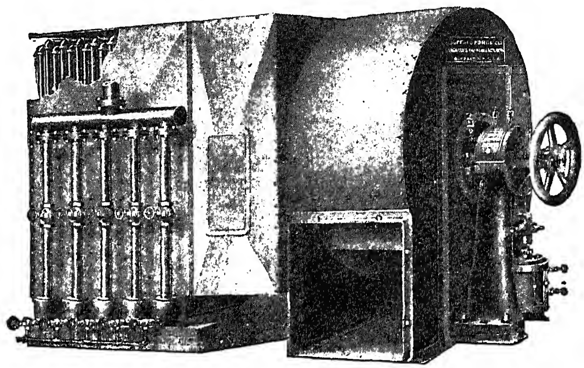


FIG. 274. BUFFALO FAN SYSTEM OF DRYING.

for the proper escape of vapor or steam by means of a stack or exhauster. Heating is effected by direct firing, hot air or by radiation from a heated surface.

With such chambers a satisfactory result is obtained only by

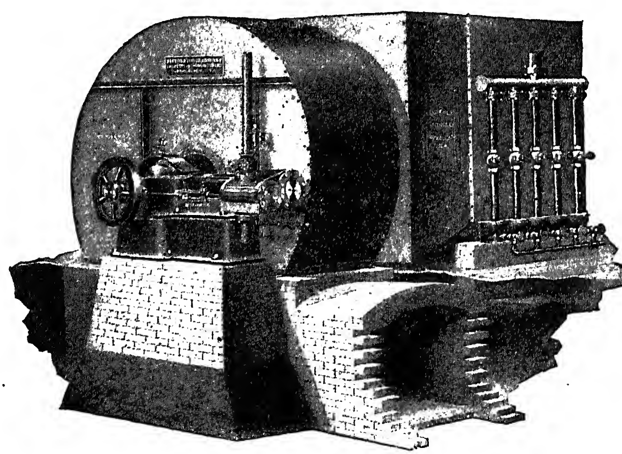


FIG. 275. BUFFALO FAN SYSTEM OF DRYING.

keeping the temperature in the interior of the chamber far above 100° C., which case is not as frequent as the application of drying temperatures below 100° C.

In the latter case the efficiency of the above arrangement is not at all satisfactory, since no more air is exhausted after the expansion of air in the chamber has reached the degree which corresponds to the chimney draft or the action of the exhauster. The evaporation of water ceases on account of too low a temperature, since the air contained in the chamber is soon saturated with steam, so that no more water is absorbed. From this moment on the heat applied is entirely wasted.

Hence, for preserving the efficiency of the chamber, fresh air has to be brought continuously to the chamber; the air is heated up, saturated with steam by contact with the material and removed so that again fresh air can enter, capable to absorb water. This principle is to be observed in all drying installations having a temperature below 100° C.

If the air is drawn through the chamber by means of an exhauster, it will pass along the shortest possible way; hence some

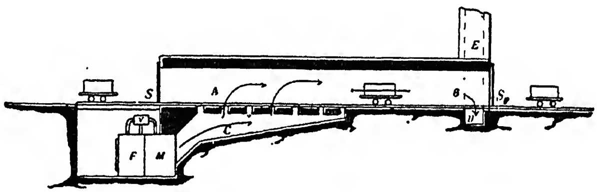


FIG. 276. DRYING CHANNEL.

parts of the material will not be dried at all, and in case of a leak, cold air will be drawn into the chamber.

A higher efficiency and greater rapidity in drying is obtained if the fresh air drawn by a fan from out of doors is heated before entering the chamber, and by pressing (instead of sucking) the air through the apparatus.

Such an installation is shown in Figs. 274 and 275. The air which is blown into the air ducts or chamber comes in contact, before entering the chamber, with a mass of steam-heated coils and is heated thereby. This heated air, having a low humidity, is now forced into the air ducts and discharged at points such as to give an even distribution. Dryers of this and similar construction are built by the Buffalo Forge Co., Buffalo, N. Y.

If a material is dried by means of admitting heated air to the material, the operation is continuously changing and becomes more and more unfavorable. It would be of advantage to change the

composition of the air corresponding to the progressing dryness of the material. This is done in practice by moving the material gradually from the point of escape of the steam to the point where the hot air enters (principle of counter current). The simplest

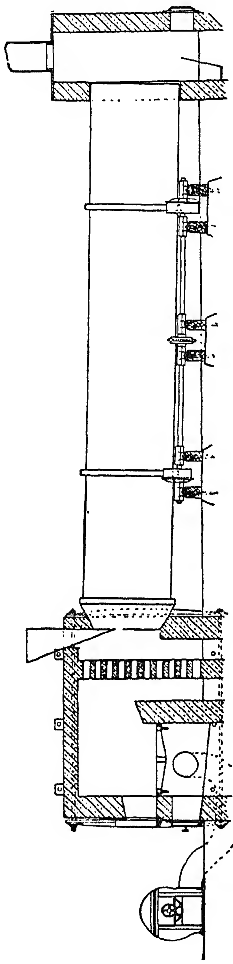


FIG. 277. CYLINDRICAL DRYER FOR DIRECT HEAT.

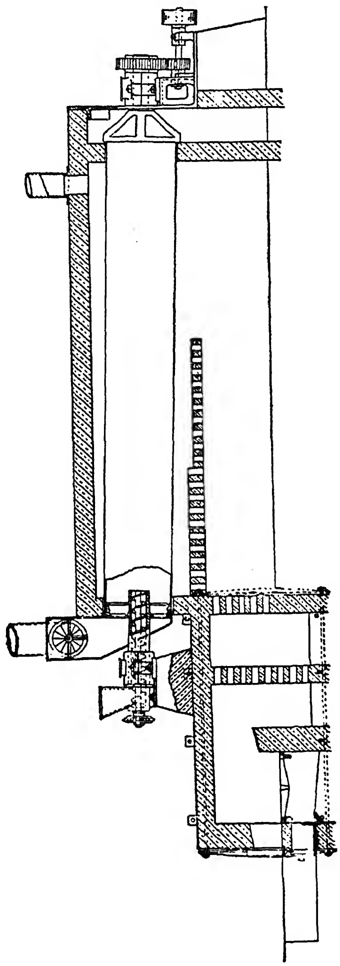


FIG. 278. CYLINDRICAL DRYER FOR INDIRECT HEAT.

plant of this kind is the shaft furnace, which, however, can only be used for fairly hard material, for the drying of which the temperature-regulation does not need to be very exact.

The so-called drying channels, which are based upon this prin-

ciple, can be used for almost any kind of material; they are easy to attend and continuous in operation. The use of an exhauster is always to be recommended, since it effects better regulation and makes the plant independent of the weather. Such a channel is shown in Fig. 276. *F* is the fire-place, in *M* the fire gases are mixed with air and travel through *C* and the channel *A* to the flue *D* and escape through stack *E*. The cars containing the material to be dried enter through the slide door S_1 and leave through the slide door *S*. For drying of materials which should not come in contact with the fire gases, this construction can be correspondingly changed.

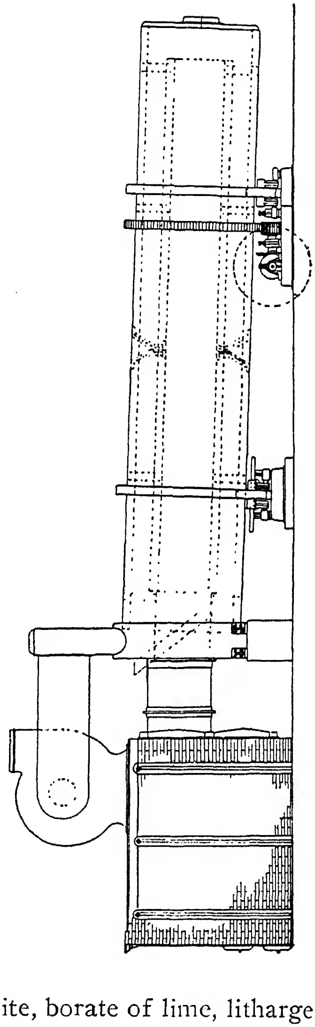


FIG. 279. LONGITUDINAL SECTION OF ROTARY DRYER (RUGGLES-COLES).

In continuous operation, seven pounds of water will be removed by one pound of coal, while when operating for ten or twelve hours per day, five or six parts of water are removed by one part of coal.

The most perfect drying appliance, wherever it can be applied, is the rotary cylinder dryer. A simple dryer of this kind is shown in Fig. 277. Fig. 278 shows the same construction adapted for drying of materials, which are not to come in contact with the fire gases.

A dryer which is widely used for drying slag, sand, gypsum, clay, chalk, pyrites, carborundum, graphite, borate of lime, litharge, etc., as built by the Ruggles-Coles Engineering Co., is shown in Figs. 279 and 280, and consists of two shells.

This dryer operates as follows: The heated air passes through the inner cylinder, shown by dotted lines in Fig. 279, and returns between the outer and inner cylinder to the fan. The material to be dried is fed into the machine through a spout in the stationary

head, which leads to the bottom of the outer cylinder, where it is taken up by the buckets or carriers and dropped through the current of heated air. It is then caught by the flights on the heated inner cylinder, which by revolving drops it into the outer cylinder, to be again carried up

This operation is repeated until, by the inclination of the machine, the material is carried to and discharged at the rear end. During this operation the material is continually dropping through the current of heated air, which is traveling from the discharge or dry end of the machine to and out through the fan at the head or wet end. The outer shell is cool through all times and the exhaust from the fan is not much above the atmospheric temperature. About 88 per cent. of the fuel value is utilized.

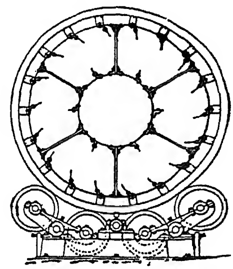


FIG. 280. CROSS SECTION OF ROTARY DRYER (RUGGLES-COLES).

The construction of the excellent rotary dryers, built by the American Process Co., of New York, is readily understood from Figs. 281 and 282.

However, in all drying installations, where the best possible fuel economy is to be effected, the counter-current principle should be applied (Fig. 283). The combustion gases mixed with the quantity of air required travel through the interior of the drum. The material is charged at the upper end at *a*, and is discharged at the lower end into chamber *b*, into which also the fire gases are entering on their way to the drum. A fan *c* keeps up the fire and also furnishes the cold air required for mixing.

A drying appliance of different type, which is successfully used for treating certain materials, is the draw plate oven (Fig. 284) built by Werner and Pfleiderer in Saginaw, Mich. It is continuous and immediately after a batch has been drawn another can be set, which operation can be repeated without any intermission. The temperature is easily regulated. This oven is very economical as regards labor, time, fuel and repairs, and requires only little floor space.

Vacuum Dryers. The vacuum drying system, now so widely used in chemical industries for drying pretty nearly every kind of organic and inorganic chemicals, was introduced in Europe by the firm of Emil Passburg, of Berlin, Germany, and the J. P. Devine

Company, of Buffalo, N. Y., has acquired the sole rights for it in this country.

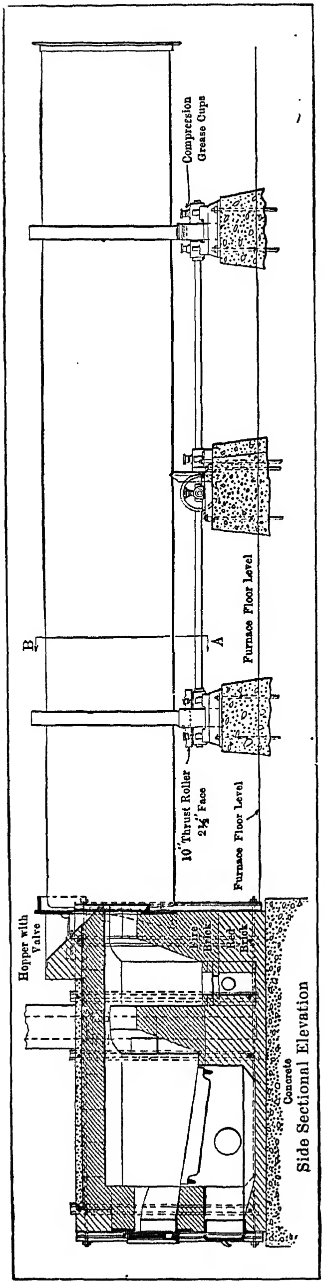


FIG. 281. LONGITUDINAL SECTION OF ROTARY DRYER (AMERICAN PROCESS CO.).

These vacuum dryers are specially designed to remove water rapidly from all materials at the lowest possible temperature and cost.

The drying is accomplished at a great saving in time, labor and fuel, as water will boil in vacuum at a very low temperature, and as all the heat introduced into the chamber is utilized in the drying process, none of it is lost.

To make this vacuum apparatus suitable for the drying of a great variety of materials of widely different chemical composition and structure, special designs have been constructed which may be divided into the following three classes:

1. *Shelf Dryers.* For materials which do not require agitating during the drying process, such as rubber, pharmaceutical preparations, explosives, sugar, salts, colors, chemicals, etc. (Fig. 285).

2. *Rotary Vacuum Dryers.* For materials requiring constant stirring and agitating during the drying process, such as grain, starch, granular rubber, fish, offal, etc. (Fig. 286).

3. *Drum Dryers.* For solutions and emulsions which will form a film such as glue liquor, tanning extract, white lead, milk, etc. Fig. 287).

1. **Shelf Dryers.** Are made in various sizes ranging from 37 to 2,300 square feet of heating surface.

The chamber contains a number of steam-heating shelves, upon which the material is placed in trays. After the door, which is made air-tight by means of a rubber gasket, has been closed, steam is admitted into the shelves (or hot water in case the material has

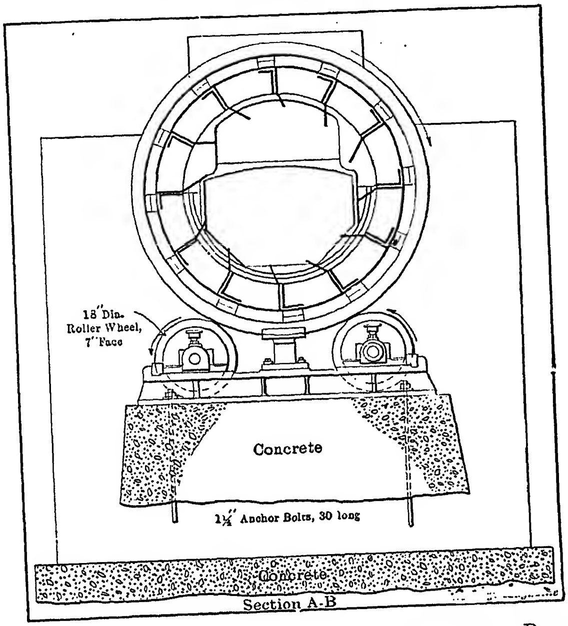


FIG. 282. CROSS SECTION OF ROTARY DRYER (AMERICAN PROCESS CO.).

to be kept at a low temperature), and a high vacuum is created by means of an air pump.

A condenser between the chamber and the pumps prevents any vapors being carried over to the pump.

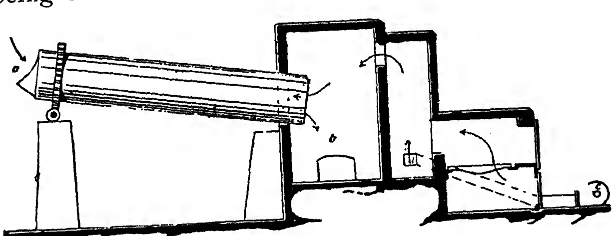


FIG. 283. COUNTER CURRENT DRYER.

Many delicate dyes, effervescent salts, incandescent mantles, India rubber, organic pharmaceutical preparations, explosives, etc., can only be properly dried in these vacuum chambers.

2. **Passburg Rotary Vacuum Dryers.** Are made in various sizes and consist of one large center-heating tube, rotating within a cylindrical vacuum shell, which is steam jacketed. Suitable pad-

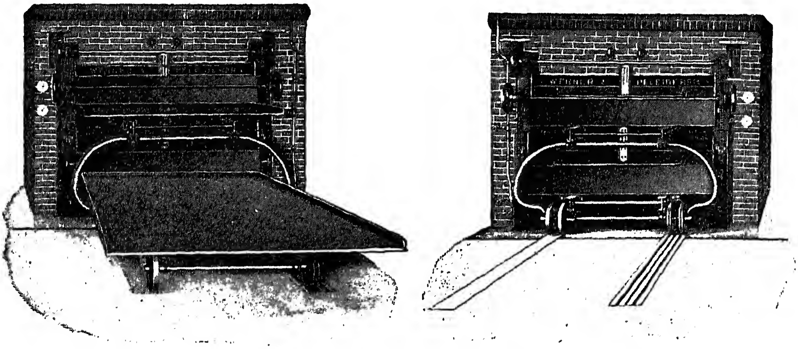


FIG. 284. DRAW PLATE OVEN.

dles are attached to the center tube, and the material is constantly brought into contact with the heating surfaces and agitated continually until thoroughly dried.

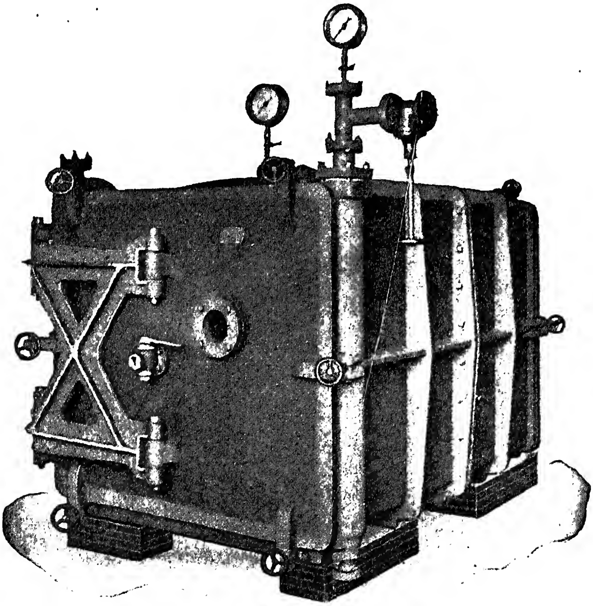


FIG. 285. SHELF DRYER.

3. **Passburg Drum Dryers.** Comprise the third class of apparatus and consist of a polished drum, steam heated internally, re-

volving within a vacuum shell and dipping slightly into the liquid to be evaporated, the latter being replaced continuously and automatically.

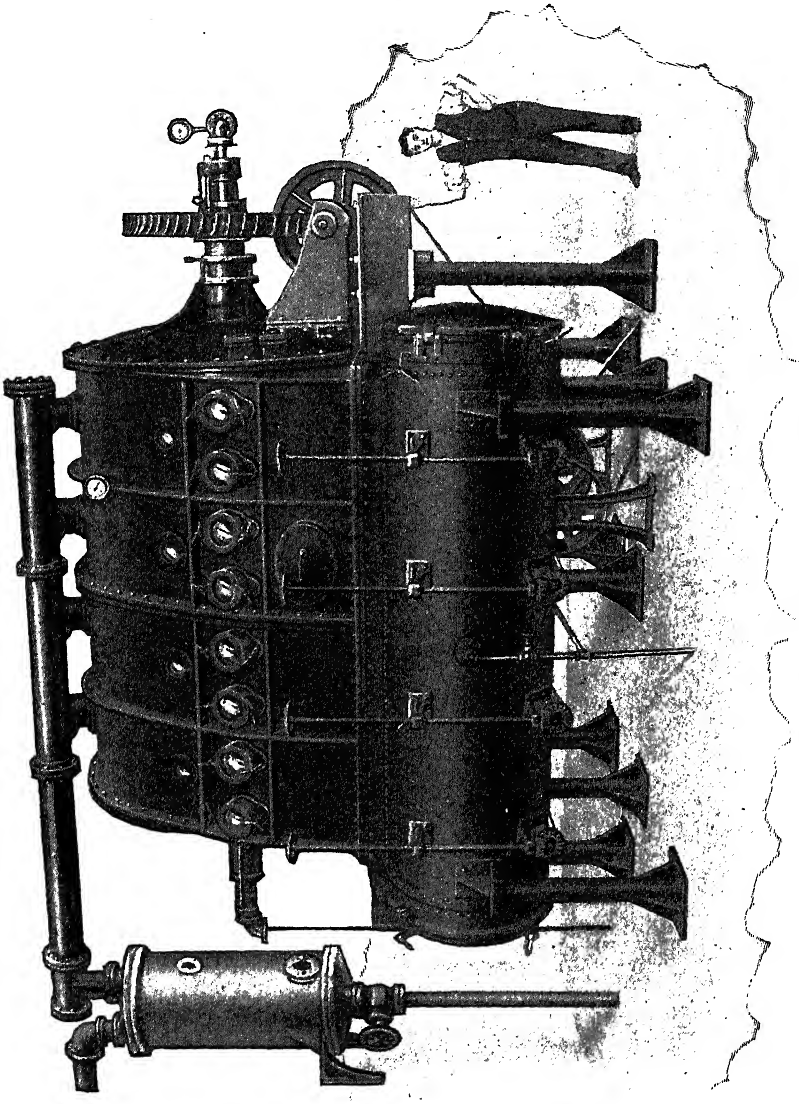


Fig. 286. Rotary Vacuum Dryer.

This liquid is deposited in the form of a thin film on the outer surface of the drum, made of cast iron, brass or copper, and is dried in about ten seconds, being then removed from the drum by a knife and drops into a receiver in the shape of a fine powder.

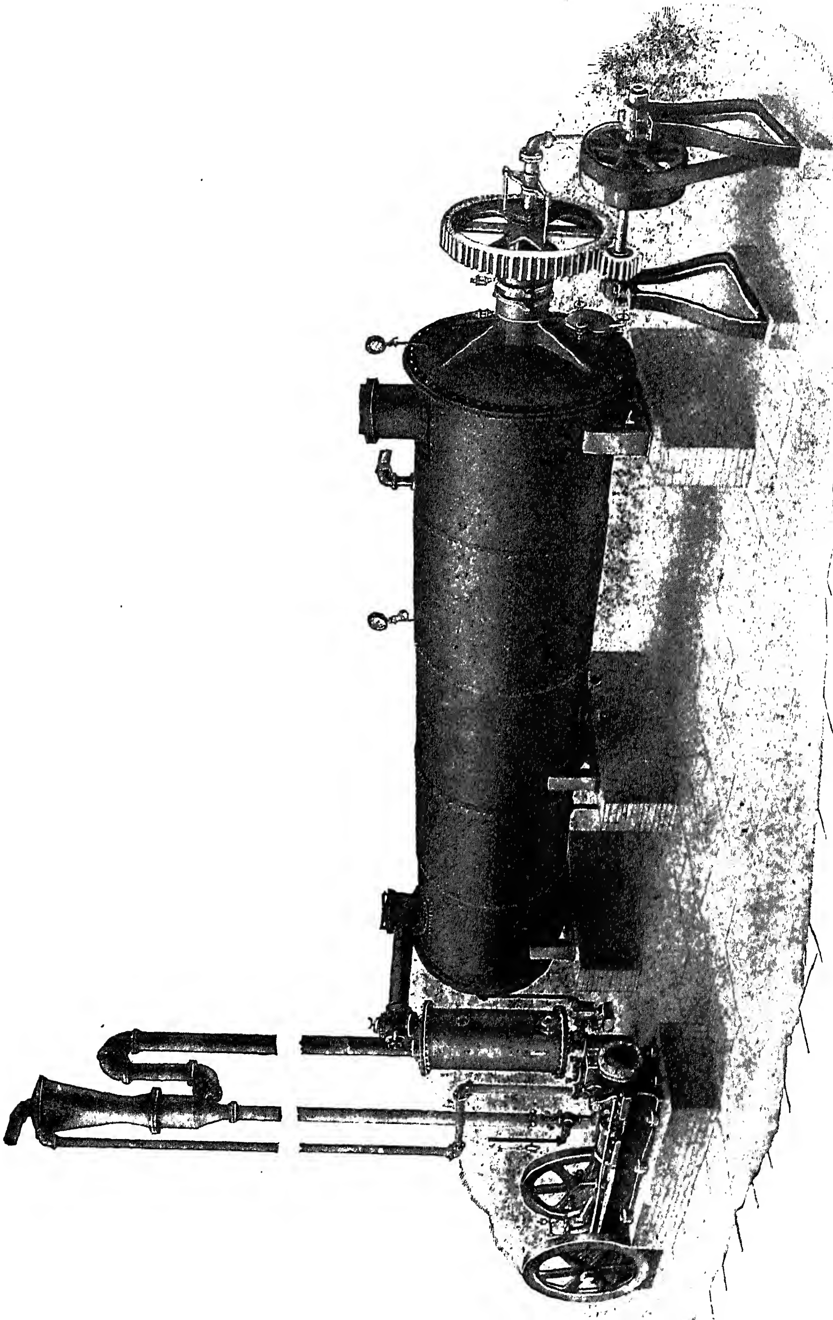


Fig. 287. Rotary Drum Dryer.

Seven different sizes of these drum dryers have been installed in this country and in Europe for drying on a large scale such materials as glue liquor, tanning extract, colors, white lead and milk.

Passburg Combined Drying and Impregnating Apparatus. The impregnating of electric coils by merely dipping them into liquid solutions and then baking in ovens has proved utterly unreliable from the start.

The firm of Emil Passburg was the first to construct vacuum vessels connected by suitable pipes and valves to impregnate coils

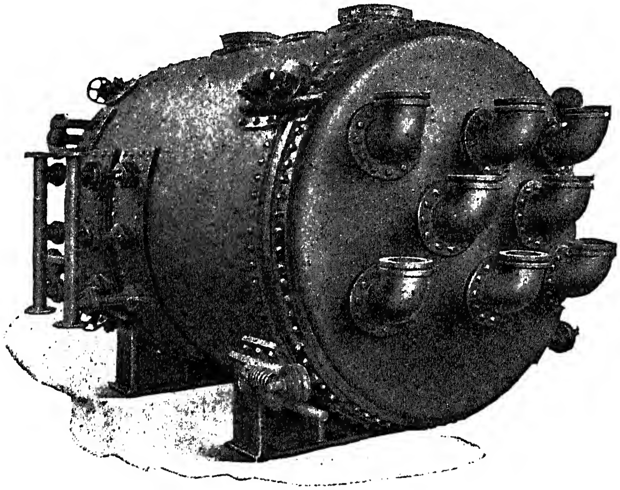


FIG. 288. SAFETY VACUUM DRYER.

with compounds of a very high melting point. The articles are first placed into the vacuum dryer and impregnator to thoroughly dry them and to remove all air from among the wires. While still under vacuum, melted compound is allowed to flow into the vessel until the articles are entirely submerged. The vacuum is thereby broken and a pressure of about sixty pounds put on to force the compound into all crevices. After a short time, the compound is pressed out of the impregnator back into the liquor vessel to allow the coils to be removed.

It will be found that field and transformer coils of large diameter are thoroughly impregnated in every part by this process. All the leading American and European electrical companies are now using the Passburg system for all transformer, armature and field coils and for the heaviest cables.

This apparatus has also proved indispensable for impregnating wood and similar materials with water-resisting and insulating substances for electrical purposes, and to increase the durability of many articles made of perishable material, exposed to excessive moisture and to other causes of deterioration or decay.

The apparatus is also used for impregnating fiber with rubber solutions and for impregnating cotton belts with heavy compounds;

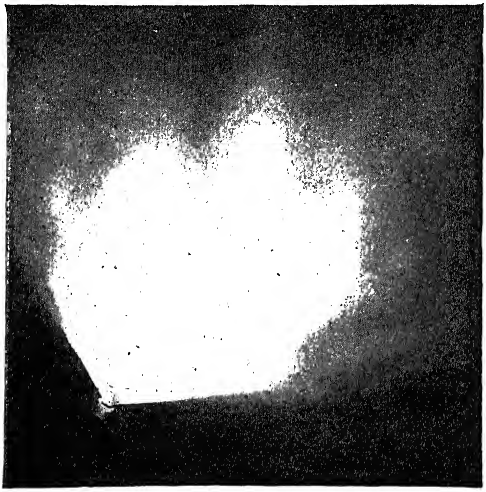


FIG. 289. NOZZLE.

in fact, new uses are found for it nearly every day in chemical industries and in the useful arts.

For drying smokeless powder, fulminate of mercury, gun cotton and other explosives, the construction of the vacuum dryer is somewhat different, to correspond with the special conditions required for drying such substances. The apparatus (Fig. 288) is provided with an expansion chamber and other safety devices for the purpose of receiving, in case of an explosion, the expanding gases and of reducing thereby their destructive power, as, before exerting any pressure on the sides of the apparatus, the vacuum in the expansion chamber would have to be destroyed. Then, any excess pressure opens the safety apertures of the expansion chamber and the gases can freely escape, thereby preventing destructive explosions. Besides the safety apertures and a very large expansion room, this dryer is also provided with a movable back cover, which is shown

in the illustration. In case the inner pressure exceeds the outer pressure (fifteen pounds to the square inch), this whole back cover will begin to move and open. For this purpose the cover is hung on rollers and held in position by springs.

With this process the time required for drying is reduced to a fraction of that required by the old process; the solvents are more thoroughly eliminated from the powder, the danger of explosion is reduced to a minimum and the solvents are completely recovered.

The consumption of the steam in the various vacuum dryers is exceedingly low. The exhaust steam of the pump cylinder may be utilized for heating purposes; about 1.5–1.2 pounds of steam are

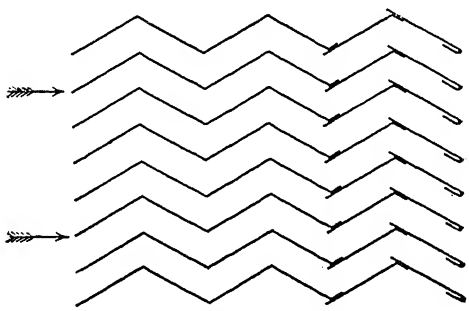


FIG. 290. ELIMINATOR PLATES.

consumed (including the steam required for the vacuum pump) per pound of water to be evaporated. Other advantages of the vacuum chambers are: saving of the floor space and labor, cleanliness and safety of operation.

The construction of a vacuum dryer depends upon the material to be dried, and the details of the apparatus are specially designed in order to suit the substances to be treated.

A well-equipped experimental plant at the works of the J. P. Devine Company is always at the disposal of manufacturers for the purpose of ascertaining by actual tests what style and size of apparatus is best adapted to the drying of the different materials. Manufacturers are constantly making use of this experimental station, and in this way the scope of vacuum drying by the various Passburg apparatuses and processes is being extended constantly, new uses and adaptations being found for it almost every day. As these tests are made free of charge, it is in the interest of every manufacturer contemplating the installation of a vacuum drying apparatus to avail himself of this privilege.

Process of Air Conditioning for Drying at Low Temperatures. Many substances, such as photographic films, gelatine, glue, etc., require drying at low temperatures. To accomplish this successfully, it is necessary that the air contain a very small amount of moisture. The temperature of the air desirable for this work is usually in the neighborhood of 60°, and for successful drying the moisture contents should not exceed three grains per cubic foot. During the greater portion of the year the moisture contents of the air are much greater than this and it is necessary that the air be conditioned by dehumidifying and cooling before it is available for drying. This may be done by refrigeration.

It may be observed that the maximum moisture content of the air at saturation is dependent entirely upon its temperature. The

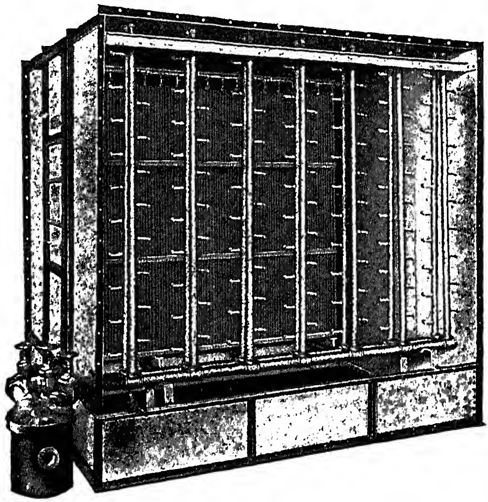


FIG. 291. WASHER AND HUMIDIFIER.

moisture-holding power of air decreases very rapidly as the temperature decreases, and if the temperature is lowered below the saturation point, a corresponding amount of moisture vapor will be condensed. The temperature of saturation, which corresponds to a given weight of moisture content per cubic foot, is termed the dew point. The dew point of air containing three grains of moisture per cubic foot is 41°. Therefore, in order to obtain air at 60° containing three grains of moisture, it is necessary first to cool it to a temperature of 41°, and then reheat to 60°. This has frequently been accomplished by use of refrigerating coils, with which

ir is brought into direct contact. This method, however, has found quite troublesome, owing to the fact that the low temure of the coils causes them to frost over rapidly, quickly

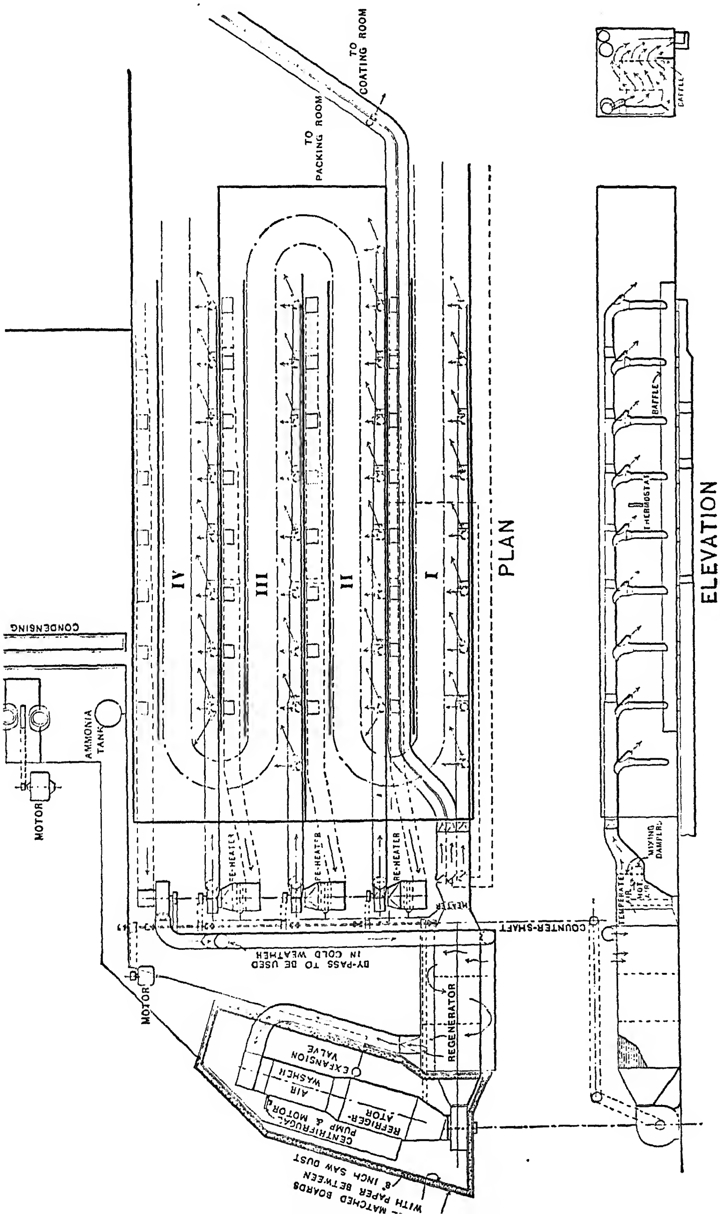


FIG. 292. FILM DRYING.

decreasing the efficiency of the system. A distinct improvement in this process has recently been made by the Carrier Air Conditioning Company, who have secured patents covering the application. This process consists essentially of introducing into the air a finely divided spray of refrigerated water at about 34° (Fig. 289). The spray together with the moisture precipitated from the air is then eliminated by a form of separator consisting of vertical zig-zag plates, Fig. 290, closely spaced, between which the air is passed at a relatively high velocity. By the centrifugal action and impact, thus produced, the moisture is entirely eliminated. By opposing the sprays to the direction of air current, tests have shown that it is possible to bring the air and water to practically the same temperature. This is owing to the fact that the enormous contact surface afforded by the spray in such a finely divided form causes a highly effective transfer of heat from water to air.

The advantages of this system, Fig. 291, are, first. that it permits the use of water above the freezing point. This allows the use of about forty-five pounds suction pressure on the compresser instead of fifteen pounds ordinarily used, thereby doubling the refrigerating capacity of the apparatus without increasing the horse-power. In other words, by this system it is possible to accomplish twice as much refrigeration as may be obtained by the older system, using either brine or ammonia bunker coils. The second advantage is that it does away with about three fourths of the refrigerating surface otherwise required. The third and important advantage is that it completely avoids the trouble from frosting of bunker coils, which has proven so troublesome in the older system.

In all cases, where the air requires re-heating after refrigeration, the above company employs an interchanger, which is a form of economizer for absorbing heat from the hot air and transferring it to the cold air. Such an arrangement frequently permits the refrigerating capacity of the plant to be reduced 20 per cent. The accompanying illustration (Fig. 292) shows a typical installation recently installed by the above company.

This process of dehumidifying and refrigerating air is equally available for use in connection with the Gayley process of refrigerating air for blast furnaces.

CHAPTER XV.

MEASUREMENT OF TEMPERATURE.

The first effort to record temperature for industrial purposes may be said to have been made by the famous potter, Wedgwood, in 1782. The instrument he devised, which depended upon the permanent contraction of clay when subjected to a high temperature, remained the standard for nearly a century.

In 1882 the famous Sevres pottery employed fusible clay to determine the temperature necessary to their work. This was perfected in 1886 by Seger, who constructed cones of clay of varying composition with fusing points ranging from 600° to 1800° C.

The substances which enter into the composition of these cones are essentially: Pure quartz sand; Norwegian felspar; carbonate of lime; Zettlitz kaolin, consisting of silica, alumina, oxide of iron and water. In very fusible cones, oxide of iron, oxide of lead, carbonate of soda, and boric acid are added. The less fusible cones contain calcined alumina. These cones are extensively used to-day and are supplied by number. The less fusible extend from 1 to 38, this latter corresponding to about 1980° C. The more fusible are numbered from 01 to 022, the most fusible being at 590° C.

While these cones are useful for the attainment of any particular temperature in a furnace, they can be no guide in maintaining a steady temperature, and can be successfully used only in such cases where a furnace is carried to the desired point and then allowed to cool off. In ceramic industry they are generally used, and before firing up, a series of cones is introduced, so that the attainment of successive temperatures may be observed by the falling over of the tips of the various cones in order of fusibility.

Other forms of pyrometers, based on the expansion of a gas or on the heat imparted to water, have been devised with a certain degree of success. With the exception of the ordinary air thermometer, which is limited in range, all the commercial instruments are empirical in character. For lower temperatures the mercury in glass thermometers is useful, but whenever such instruments are used for the higher ranges up to 1000° F., they deteriorate rapidly

and soon give inaccurate indications. The instruments most generally used for temperatures up to 2600° F., are based on the thermoelectric properties of the metals discovered by Seebeck in 1820, and applied by Becquerel for temperature work in 1830. Le Chatelier made an extended study of the thermoelectric pyrometer and showed that pure platinum, when combined with platinum alloyed with 10 per cent. of iridium or rhodium, could be used up to 2900° F.

These instruments consist of a pair of wires fused together at one end for insertion in the furnace and fastened to copper wires at the cool end. The connection is made to a galvanometer or millivoltmeter, and the temperature is indicated directly on the scale. The correctness of reading depends as much on the cold ends as on the hot end, and hence great care must be exercised to have the wires of the couple sufficiently long to be away from the influence of the furnace. In the case of the Le Chatelier couple this is an expensive matter. To obviate this and also the expense attached to a chance deterioration of the couple from contact with furnace gases or hot metals, Prof. Wm. H. Bristol offers a nickel-iron couple with a patent compensated cold end, which has the advantage of being self-contained, unbreakable, and cheap.

One disadvantage of the thermoelectric pyrometer is in the fact that the reading instrument must be calibrated for a certain length of connecting wires, which when altered change the indications. The instrument is its own battery, and is therefore simpler than many others.

Recording devices are available for the thermoelectric instruments. The galvanometer or millivoltmeter needle, bearing a point or pen, moves across a scale on which it is depressed at regular intervals of time, thus tracing a dotted curve.

The electrical resistance pyrometer is extensively used in England, and depends on the variation of the resistance of a pure metal —such as platinum—with temperature. As originally devised by Siemens with a fine platinum coil, the instrument was not successful, and it was not until Callendar took up the matter in 1887 that it was made practical, not only as an ultimate laboratory standard, but as a commercial instrument. It may be said to be at the present time the most useful instrument for all classes of temperature work. It is limited in its upper range, however, to about 2200° F., beyond

which the platinum wire coil volatilizes and permanently changes in resistance. The instrument is based on the well-known Wheatstone bridge principle, and requires an external battery. It is very nearly independent of battery voltage, however, and is affected only by currents large enough to heat the fine wire coil. By the introduction of compensating leads, which parallel the leads running from the fine platinum coil to the indicating galvanometer or bridge, and which are connected to the opposite arm of the bridge, the readings are independent of the distance between the fire end and the reading instrument.

The indications are obtained on deflecting galvanometers, or on wire bridges with direct reading scales. A recording device has been obtained by Callendar which is capable of great refinement. It is essentially an automatic Wheatstone bridge. A galvanometer with double contacts operates a right and left hand relay device connected with a differential gear operating the galvanometer contact on a bridge wire. The record is traced on a drum by a pen attached to the galvanometer contact. The relays move the contact always in such a direction as to restore the balance whenever this is upset by a change in the resistance of the platinum coil due to a change in temperature. Telephone indicating instruments have been devised to replace the galvanometer with much success.

Other forms of pyrometers have been devised, based on the ordinary gas thermometer, such as the older form of Bristol instrument. Instruments employing a stream of water flowing through a coil in the furnace have been devised in which the difference in temperature between inflow and outflow gives an indication of the temperature of the furnace. Such an instrument depends entirely on maintaining a perfectly steady flow.

The flow of air through an orifice in the furnace has been utilized, the change in the viscosity of air and size of the orifice giving the necessary variability of flow upon which the temperature indications are based. These instruments depend entirely on an empirical calibration.

In very high temperatures the only satisfactory instruments are the optical pyrometers. These are of two classes: those that depend on color estimation, such as the Wanner, and those that depend on the measurement of the total radiation, such as the Féry pyrometer. These instruments are coming into very general use and ex-

tend in range from a low red heat up to the temperature of the sun itself, 6000° C. For the latter instrument, recording devices are available similar to those used in connection with the thermoelectric pyrometer. The laws of heat radiation are now well known and the instruments based on these are found to give exceedingly satisfactory and reliable indications.

In general it may be said that for very high temperatures, from 2200° F. upwards, the only reliable instrument is the optical pyrometer. For a commercial instrument reading from 2600° F. downwards to about 300° F. or 400° F., the thermoelectric pyrometer, such as the Bristol, is the most serviceable. For work below 500° F. down to the temperature of liquid air, no instrument can compare with the electrical resistance pyrometer. As a standard over the whole range of temperature up to 2200° F., the resistance pyrometer is undoubtedly the best. It is not too much to say that all industrial concerns should provide themselves with one of these to check the indications of other instruments from time to time.

Too much attention cannot be given to an accurate knowledge of temperature conditions in industrial work, since the success of so many processes depends to such a large extent on the attainment of steady heat.

APPENDIX.

THE WORKS CHEMIST AS ENGINEER.[1]

All chemical works have, in addition to purely chemical and exclusively manufacturing questions, a large number of engineering problems to solve. In fact, chemical manufacture requires quite as much attention from the engineering as from the chemical side. Very large chemical works can afford to have an engineering department, and even smaller works can, and very frequently do, employ with advantage a special engineer. Most works, however, under present conditions in this country, possess a more or less adequate staff of analysts and one or more well-trained foremen, but in order to grapple with the engineering problems, they rely either on the mechanical skill of the average Englishman or on some special talent in their works combined with what technical knowledge the average chemist can bring to bear on the matter.

I doubt whether many chemists ever pictured to themselves the surprisingly large amount of engineering work and control required in an average chemical factory.

When deciding on material for buildings and plant, the nature of the products to be manufactured and the products incidental to manufacture have to be carefully considered. The questions will arise: Are the raw material, or the finished product, or the effluents, acid or corrosive, or likely to form dangerous or noxious compounds under certain conditions? Are there any special fire or other risks, which ought to be known to the man responsible for the design of the plant or building? Obviously, not every kind of brickwork, concrete, or stone, nor any metal will do for every purpose, so that the apparatus, pipe lines, storage tanks, and many other parts of the plant, have to be considered individually. Thus, to take a well-known example, weak sulphuric acid is best contained in lead, but strong sulphuric acid in iron. Strong nitric acid can be handled in lead, but not so well in iron, whilst a mixture of strong sulphuric and nitric acids is safe in iron. Hydrochloric acid in

[1] From a paper read by Oscar Guttmann before the Society of Chemical Industry.

time attacks almost any material, except silicious stone, earthenware, and ebonite; hence the latter substance is frequently used in pumps. Furthermore, hydrochloric acid scarcely attacks wood, especially if the latter is soaked in paraffin wax; hence on Continental railways it used to be carried in wooden tank trucks. Citric acid is one of the few substances which attacks silica, so that, for instance, kieselguhr cannot be used to filter it. Oxalic and tartaric acids cannot be evaporated in copper, but in lead only, while pure acetic acid is best worked in silver stills. In a similar way the material for the flooring has to be carefully selected.

The roofs require no small consideration. Not only is a roof probably that part of a building which costs most for upkeep, but the safety of the plant and operations frequently depends upon its good state, which should prevent rain, sand, or cold draughts to enter the building. It is frequently advisable to make the roof trusses of such strength as to allow shafting to be carried or pulley blocks fixed for hauling up materials and apparatus. In very many cases pipes and other ducts are best carried across the roof principals, provided these are not overloaded.

A very important part of the duties of a manager is the installation and supervision of the power house. Much depends, of course, upon the size of the factory and the quantity of steam or power required. Sometimes strict economy of fuel is not of paramount importance, though, in most cases, every penny is worth saving, because it is conducive to the better supervision of the plant. The choice and relative advantages of the various forms of prime movers, whether steam, water, gas, suction gas, or oil, need not be discussed here. Suffice it to say that any engineering knowledge he may possess will enable the manager to discriminate between the claims of rival makers and save him much ulterior disappointment. It is rather in the working and upkeep of such plant that his knowledge and skill will be of the greatest service. Naturally, in the case of a steam plant, fuel and water, and in the case of a gas plant the coal should be analyzed from time to time and their suitability and value thereby determined. It will be found useful to instal a water meter and keep daily records of the quantity of water evaporated and of the amount of coal consumed. An intelligent manager will be able to draw therefrom many conclusions with regard to the working of the factory generally. If he knows how to do it, he will

even from time to time test the efficiency of his plant by making complete steam trials and thus trace any undue source of loss or waste. He must ascertain that his boilers are not given to "priming," *i. e.*, delivery of wet steam. He will test his flues from time to time, or, better still, instal an automatic carbon dioxide recorder. Everybody is aware that by the admission of more air a better combustion of the fuel results, but not everybody realizes that by admitting too much air one cools the flues, and gets an irregular draught and imperfect combustion. A large economy of fuel can be obtained by simply tarring the brickwork from the outside, thus rendering it fairly impermeable.

In connection with boilers and engines, a large number of appliances are daily recommended, which are each supposed to effect such a saving that, were the totality of them taken, the consumption of coal should be practically *nil*. The fact is, however, that in large installations economies are easily effected, whereas in the case of single boilers and but little machinery, the attention of a small *personnel* has to be devoted to too many appliances at the same time, to enable them to effect a saving.

Automatic stoking and automatic feeding of boilers are very desirable additions to a boiler plant, the more so as one thereby generally obtains nearly smokeless combustion as well. Works that cannot afford such outlay, will do well to go carefully into the question of their grates. It is really surprising how rarely one meets in this country with special grate-bars, designed to give a maximum area for the admission of air, and yet permitting the use of small fuel; very large economies can result from a proper adaptation of grate-bars to the nature of the fuel.

To judge from the relative merits of the many smoke preventers on the market requires no mean engineering skill, because although the question is really a chemical one, the means to carry it out are for the most part mechanical. Some smoke preventers blow air through the fire-door over the coal, some under the grate, through the coal. Others blow steam and air over the incandescent coal from the front; again, others blow it in from the back of the grate, and induce air at the same time. Some have mechanical means to gradually close the fire door after coal has been charged, some have adjustable louvres, and so forth. It is indeed very difficult for the

average chemist to arrive at a decision, even though many makers offer to put the plant up on trial, and remove it at their own expense.

Modern water softeners may be divided into three main classes. In the first, the softening medium is added alternately to the water contained in two tanks; the contents of one are allowed to settle, whilst the purified water is fed from the other. The second system is one in which hard water and softening medium are introduced in measured quantities, by a tipping arrangement, chain buckets, water wheel, or other similar device. In the third class, the mixing is effected by means of floats attached to levers, which open or close cocks for the admission of hard water and the softening medium in their correct proportions. They may, again, be subdivided into those in which the reaction between the softening medium and the hard water is promoted by heating with exhaust or live steam, and those where the work is done in the cold. These may be further subdivided into apparatus in which the sludge separates out by precipitation over baffle plates, and such in which this is effected by means of filters. One has to see that no excess of softening medium is carried into the boiler, and that the sludge is efficiently removed; further, that the apparatus is easily manipulated, and not liable to get out of order. All other things being equal, the choice between rival claims will rest with the apparatus which does the work more cheaply. The question of economy does not, however, depend upon the cost of the chemicals per 1000 gallons of water only, more frequently initial outlay and cost of labor being the deciding factor.

Feed water heaters and economizers are also frequent adjuncts to a boiler plant, and require attention. A careful engineer will not be satisfied with the mere cleaning of the boiler; he will pay proper attention to the kind of scale deposited, and learn something, either by personal inspection, or from the reports of the boiler inspector, about the nature of corrosions in boilers, and the dangers arising therefrom.

A further problem that frequently presents itself is the utilization of the exhaust steam from the engine, or else its condensation and subsequent recovery as boiler feed. Exhaust steam can be very advantageously used to heat the water in water softeners, and thereby be recovered practically without cost. The cooling of water used for the condensation in the absence of an unlimited supply

necessitates large towers and pumping plant, which demand further attention, space, and capital outlay.

The next important problem bears on the distribution of steam over the works. Although it is a very rare occurrence to find nowadays steam pipe lines in the open air which are not covered more or less with insulating composition, yet they are very frequently found bare inside workshops, it evidently not being realized by everybody how serious a loss in fuel is incurred thereby The difference even between one insulating material and another is large enough to repay a proper study of the question.

Very frequently it is necessary to convey steam from the boiler-house to a number of separate buildings, and, possibly, very large distances have to be traversed. If the steam-pipe is a very large one, and a number of other pipes for compressed air, water, and perhaps also electric light leads, have to be carried to the same building, then it pays very well to have either a regular bricked trench accessible through manholes, floor plates, or otherwise, or even a passage sufficiently roomy for a man to walk through. In this case, it will be possible to rest the steam pipes on proper brackets or bases, provided with rollers and expansion joints. If, however, the steam has to be carried in one or several pipe lines of small diameter (say up to about 2 ins.), it will be simpler to carry them above ground on trestles. Whilst it is quite possible to carry such pipes on rollers, expansion joints are not suitable, because the pipe is apt to give way in many places, and then the whole arrangement for taking up the expansion of the metal may fail.

The question of steam distribution brings us to the problem of collecting the condensed steam. As this represents a source of supply of the purest water, every drop of it ought to be collected for the boilers. Such water does not condense in the steam pipes only, but to a much larger extent in apparatus for boiling and concentrating liquids. A judicious use of properly acting steam traps, and some expense on covering material, will save a great deal of money. When there are a series of boiling apparatus, such as steam pans, to be supplied with steam, the pressure of the steam must nearly always be reduced, so that its temperature may not exceed the boiling point of the liquid in the pan, or in order to conform to other conditions. A really good reducing valve is rare, and the best is useless if not properly attended to. Non-return valves must be

attached to the steam traps, as otherwise a single leaky one may prevent the whole of the pans from working properly.

Of steam engines the varieties are legion. My advice is take the best that money can buy, one that has every possible improvement for its size, and is made from the best material and in the best style possible. To have no trouble with repairs, not to have to stop just when everything works smoothly is alone worth a great deal, quite apart from the fact that the best steam engines repay the larger outlay simply by their constancy and economy in working. I do not intend to deal with the respective merits of gas engines, oil engines, steam engines, steam and water turbines, etc. I can only repeat—buy the best, and to the chemist my advice is: Learn to understand your plant and to know all about it, so that you need not rely upon the sometimes fanciful reports of an engine driver.

The proper lubrication of engines, shafting, and bearings does not merely depend upon an ample supply of lubricant, but the chemist should also keep his eye on its chemical nature and on economy. It has happened in my own experience that cylinders and pistons of very fine steam engines were badly scored, and blame was put upon the chemicals used in softening water for the boilers. My suspicion that the lubricant was acid was promptly confirmed by chemical examination.

The transmission of power from one building to another is, again, a constantly occurring problem, and one that is not always judiciously solved. Few people are aware that as much as 40 per cent. of power can be wasted in defective shafting and gearing. A very efficient means of transmitting power at an angle was provided by me some time ago in a place where a pair of bevel wheels was so badly worn, and the lines of shafting so badly laid that the building was constantly shaken and a great deal of noise produced, not to speak of the enormous loss of power. This angle-drive is constructed for transmitting 40 horse power. One of the largest makers of shafting was asked to supply it, but he did not think it could work, and it was only after he had consulted a professor of engineering, who gave him some hope, that he carried out the order. This is now some years ago, and the transmission has never stood still since. In making such an angle-drive care has to be taken that the points at which the belts leave the pulleys are exactly above each other, as otherwise the belt will fall off. This arrangement

will transmit power in one direction only for any given arrangement of the pulleys.

It is, of course, very rarely possible to transmit power from one house to another by means of belting. Sometimes very long ropes have to be used, and the amount of sag then necessitates very high and strong supports for the pulleys. Both in this case and when the power is transmitted to an adjacent building by means of a continuation of the shafting (either underground or above ground), a good deal of attention in laying out as well as in keeping up such an arrangement is required to prevent a serious loss in efficiency. Electrical transmission is very frequently the best and most economical solution. This at once brings before us the question of lighting a factory. Great care has to be bestowed on this point in some works, where serious responsibility is attached to any fault in this direction. If an electric installation is provided, advantage may be taken of it to transmit power to distant parts of the factory, to drive fans in otherwise inaccessible places, to supply delicate heating arrangements, or even for electrolytic work.

Many engineering details require to be attended to in connection with the handling of liquids. The pumping of liquids from one apparatus for use in another is almost a study in itself. Whether steam- or belt-driven, plunger or centrifugal, pulsometer or membrane pumps should be used, or whether delivery of a liquid should be effected by means of elevators (montejus), and of what material these pumps and the pipe lines should be made is rarely a matter of indifference. In this connection fans for carrying away fumes, for improving the draught (as in the manufacture of sulphuric and nitric acids), for supplying air to a drying room, and for many other purposes are worthy of mention. How difficult it sometimes is to do the right thing may be illustrated by a few examples from actual experience. A plunger pump refused to work with a hot volatile liquid until an air-vessel was interposed, wherein the vapor could condense. A pulsometer placed into a narrow unventilated hole could only be brought to work after the place had been rendered cool by proper ventilation. A number of acid elevators, made of cast iron, one and a half inches thick, burst at short intervals under thirty pounds pressure, although they had been tested up to 150 pounds; on investigation the cause was found in that long pipelines going to a higher level were fitted to these elevators, and that

a bend at the end of the line favored water-hammer action. Both in this country and in America, aluminium fans, pipes, etc., in connection with nitric acid, are coming more and more into use, whilst in Germany, and also in this country, earthenware fans and centrifugal pumps are preferred in acid works.

The supervision of effluents, both liquid and gaseous, requires considerable care. The choice of proper culverts, gutters, or pipes, depends frequently on the nature of the effluent, and when liquid effluents are sent into a sewer or a watercourse tests have to be made, sometimes for considerable distances, to avoid trouble with local authorities and interested parties; arrangements may also have to be provided for catching suspended matter, precipitating impurities, or for rendering the effluent clear or pure before admitting it into a watercourse.

Compressed air and vacuum pumps are important factors in chemical works. Both kinds are similar in construction, but the efficiency varies very much from maker to maker. Whilst in the case of an air compressor a proper volumetric efficiency must be demanded, and may be obtained if reasonable care is taken, the barometric effect is all-important in selecting a vacuum pump. Some processes are now so well regulated that a difference of a few millimeters in the vacuum entails considerable loss of time and cost. Some works are already demanding a guarantee for a vacuum of two millimeters with very large pumps, and, what is more, they get even one eighth millimeter. Reservoirs for storing compressed air and allowing it to cool are better not left alone, as usual, because, apart from condensed water, there have been explosions in such, and also in pipe lines, which were found to be due to hydrocarbons from the lubricant.

In addition to having so much detail work to attend to in the factory generally, the works chemist requires still further engineering knowledge of his plant. Mr. George Beilby, F.R.S., gave us, in 1899, a long list of apparatuses required in chemical work. Of course, the chemist is rarely called upon to construct an apparatus or a machine, but he must have a working knowledge of those in regular use for all kinds of operation, and if he invents a new process, then he should be able to indicate his requirements for work on a large scale. Like Mr. Beilby, I, too, wish to emphasize most strongly that "works operations are not simply laboratory opera-

tions writ large." It is frequently easy to indicate a new process by small operations in the laboratory, but when the chemist is called upon to reproduce the process on a large scale, then far more real inventive genius is required to design the plant for its manufacture, and it may take months before all the difficulties are overcome and the process begins to pay, if indeed it does at all. It is, therefore, useless to teach chemical technology with the help of beakers and test-tubes. A striking example was shown recently, when candidates in an examination were asked to sketch out a filter for continuously filtering a hot liquid. Every one of the candidates showed a steam-heated funnel, and only one had the additional notion, that for continuous work on a large scale a filterpaper might prove impracticable, and therefore devised a sand filter. With better experience it would, however, have occurred to them, that a filter is not necessarily round as it is in the laboratory, and that a number of rectangular filter papers placed over suitably shaped steam or hot-water compartments might allow of large quantities being dealt with quickly.

It is useless to ask the average engineering works to advise on all possible plant, since only very large works have a sufficient number of experienced engineers for every purpose. On the other hand, it is always possible to find such works that make a specialty of certain machines and apparatus, and their experience is, of course, valuable. It is in the construction of apparatus, and appliances for chemical processes, involving no mechanical arrangements, like plain stills, evaporating pans, lead, cooling and heating tanks, even vitriol chambers and towers and the like, that the chemist will find his engineering knowledge useful.

Similarly intelligent attention must be given to the methods of heating. Regenerative firing or "plus pressure" in a salt cake furnace, overhead firing in sulphuric acid concentration or evaporation of liquors, firing with water gas or producer gas, heating by ordinary or superheated steam, under pressure or in vacuo, boiling in an oil or lead bath, evaporation by waste gases, calcining, roasting and many other processes of heating all are beset with problems for the chemist and the engineer. An example may be taken as an illustration. In a furnace a series of vessels for the concentration of sulphuric acid were to be heated by producer gas, the flames playing all round them. Up to a certain degree of concentration all

went well, but beyond that no amount of gas burned produced further concentration. Consideration showed that as producer gas contains about 20 per cent. of hydrogen, the products of combustion were quickly saturated with water vapor, and then their vapor tension was the same as that of the vapors escaping from the acid. When the gas producer was replaced by a simple regenerative coke furnace, the concentration proceeded smoothly.

The condensation of gases, or their absorption in liquids, the drying of pasty or dusty materials, or of such that must be dried at a certain low temperature, and the recovery or the rendering harmless of gases driven off, the filtering of cold and hot, acid and basic liquids, etc., are again processes applied in so many variations and from the largest to the smallest scale, that I need only point to them as constantly requiring engineering skill and attention.

It serves no further purpose to go on enumerating the many every-day operations in chemical manufacture, each one of which requires engineering as well as chemical knowledge. A most important duty must, however, not be overlooked—economy. To have wonderful and fanciful apparatus constructed, to use the most expensive materials, and to let them be made with the greatest care, is easy; to devise apparatuses, that cost no more than the process can stand, and that will give no trouble in working, is more difficult; but to make them give the best results at the least cost requires that the chemist must be able, as Mr. David Howard expressed it so tersely, "to think in tons." But, even apart from construction and working what a large field has a chemist in which to show his talent for economy! I have known a factory where three men were deputed to pick up every nail, every piece of wood or sacking or other waste material that had been thrown about by careless men under careless supervision in past years, and their two days' haul brought quite a large sum of money. I have known others where faulty air compressors required almost daily renewal of valves, where the number of leaky steam valves and water cocks found on the scrap heap was more than a hundred, where the steam wasted through leaky joints caused considerable nuisance at considerable expense, and yet all these could have been prevented or repaired at a small weekly cost, and the waste material made useful again. A chemist can in a hundred and one ways make himself highly valuable by looking after little engineering details, and he will become still more useful by

being able to look after the building of small works railways, the provision of lifts, the erection of storage tanks for liquids of all kinds, the care of packing materials, like carboys and casks, the safety of the factory and workers against fire and accidents, and many other things.

After having, much to my gratification, patiently listened to this long syllabus of possibilities for a works chemist to act as engineer, you will, no doubt, be inclined to ask where the heaven-born genius should come from who can do all that work. To perform all these functions thoroughly requires a well-trained engineer with a large experience in chemical works, and, as Mr. Paton once explained, not merely a superior mechanic. It is useless, therefore, to expect a chemist to undertake all such work. On the other hand, a works chemist ought to possess an adequate knowledge of chemical technology to enable him to understand all kinds of plant, to give proper instructions to the artisans in the works, to confer with specialists in case of improvements, and to settle details with them, as well as to work the plant afterwards.

In these days of great competition and scientific progress, a foreman, risen from the ranks, will only very rarely be able to act as a works manager. True, a number of men are still with us, who have worked hard to gain scientific knowledge, and to combine it with their practical experience. Such men have been amongst the founders of the enormous chemical industry of this country, and we are proud of those still working and those coming on. The future, however, belongs to the chemist who has gained practical experience as foreman of a department, and combines therewith a good engineering knowledge. Such a chemist ought to be properly trained, and that cannot be done with young men who come to college imperfectly prepared, and certainly not in three years, as prescribed at present; there ought to be another year added, so as to teach more mechanics and physics in the beginning and to give a proper course of chemical technology in the end.

Now there is only one thing more wanted, and that a most important one, namely, that manufacturers should realize that a works chemist is not solely an analyst, but a highly useful practical technologist, who, given a little confidence, will in a short time repay his salary many times over, and make them wonder that they could ever have done without him. And, after all, most chemical works

are nothing but huge shops full of machines, which in monotonous sameness grind away at well-established processes, where there is little work for the pure chemist, but a great deal when he also has good engineering knowledge.

We have heard too much about the many chemists engaged on research in the large color works of Germany. Highly valuable as they are, and important as their discoveries were, the German chemical industry is infinitely more indebted to that far greater number of works chemists who patiently and thoroughly investigated the manufacturing processes, who had the ability to devise improvements and economies, and who found generous manufacturers and their college-trained sons to give them their confidence. It is on these lines that we must progress.

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